Using Digital Twins to Improve Visibility of the Military Supply Chain

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Abstract

To ensure the effectiveness of combat operations, the military supply chain (MSC) must be effectively monitored for supplies and timely choices must be made, especially in the face of unforeseen obstacles like inclement weather and terrorist strikes. Even though Next-Generation Wireless Communication (NGWC), RuBees, and RFIDs are used in MSC, they are insufficient to guarantee end-to-end visibility throughout the whole SC. The internet of things, cloud computing, application programming interfaces (APIs), machine learning, augmented reality, virtual reality, big data, analytics, and pervasive computing are examples of digital technologies that play a crucial role in boosting visibility to enable effective SC management. Consequently, the development of the idea of the "digital twin," made possible by modern technologies, produces a digital copy of theextensive supply chain.Using real-time data, operations are ensured to have enough end-to-end visibility, allowing for efficient tracking, monitoring, and reporting of all SC actions. This paper's main objective is to examine the digital twin's enabling technologies and implementation to achieve end-to-end visibility in the military supply chain. The tracking and monitoring capabilities of the digital twin, which the authors identify in this research, will enhance supply chain management by enabling a cycle of continual SC adjustment against unforeseen disturbances.

Keywords:

Military supply chain, Visibility, Tracking, Monitoring, Digital twin.

1.Introduction

To ensure the effectiveness of combat operations, especially in the face of unforeseen disruptions like inclement weather and terrorist attacks, the military supply chain (MSC) requires effective monitoring of supplies and prompt choices. Military logistic planners are being forced by this problem to rebuild their supply networks so they can be more proactive in observing, following, and reporting on all supply chain operations. On a result, the idea of end-to-end SC visibility was introduced, increasing the visibility and transparency of the supply chain [1]. This is made possible by technologies likeRuBees, NGWC, and RFIDs are examples of next-generation wireless technologies [2]. Although used in the military supply chain, these technologies have not been adequate to guarantee effective end-to-end visibility. Network security, insufficient or misinterpreted information, and technological difficulties may be to blame for this [2, 3]. [4] asserts that in order to reduce freight theft or loss, facilitate the substitution of transported goods, and foster consumer confidence, visibility is essential in the SC.

developing consumer confidence and moving goods.

With the recent introduction of digital twins made possible by digital technologies like the Internet of Things, cloud computing, APIs, machine learning, augmented reality, and virtual reality, supply chain visibility has improved. These technologies can increase supply chain visibility and offer real-time data, enabling complete control and confidence (Sunil, 2020). A digital SC twin, according to [5, 6], is a model that depicts the state of a network at any given time, enabling end-to-end SC visibility in order to improve resilience and a reliable contingency plan. In order to facilitate planning and prompt decision-making, Hosseini, Ivanov, and Dolgui (2019) note the potential of the digital twin in supply chain monitoring of "transportation, inventory, demand, and capacity."With its advantages in generating cost-effective solutions and boosting efficiency and quality, digital twin technology stands out among emerging technologies in the military [7]. Time is a crucial component in the military, thus digital twin technology will help systems run more efficiently and enable decision-makers to act quickly when necessary [7]. Decisions.The paper's purpose is to investigate the advantages and application of the digital twin inside the military supply chain. This investigation will show locations where the digital twin has been used or those that require more study.

2.Visibility of the military supply chain using current technologies

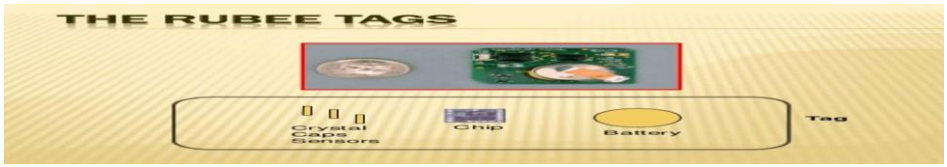
A Radio Frequency Identification Device (RFID) is a small tag with an antenna and an integrated circuit that can respond to radio waves sent by an RFID reader to transfer, process, and store data [2]. The earliest application of RFID occurred during World War 2, when allied troops utilized radio waves to collect data from tags to ascertain the loyalty of combat aircraft [8–11]. Since that time, the technology has been used in other industries to automate product authentication and tracking, thereby resolving or at the very least minimizing the negative impacts brought on by poor management or attacks against the weakest link in the supply chain [12].By recognizing automatically tagged goods at transit nodes and ensuring data collection, RFID uses radio waves to provide visibility [13]. RFIDs are used by the military to automatically identify and locate logistical goods as well as to locate and direct shipments [14]. For instance, according to military officials, the integration of data from satellites, RFIDs, and other technologies greatly aided in asset tracking and visibility during the Iraq battle in 2001. [15] conducted research on the use of RFID and pervasive technology in Iran's military garrison supply chain. Results indicated increased process efficiency, speed, and information correctness. The difficulties in adopting RFID, as stated by [3], include technical dangers, the prevalence of barcodes, and privacy concerns. Other difficulties include those related to technology, patency, infrastructure, and barcodes.

Figure 1. Miliatry assets tracking [14]

The Department of Defense (DoD) is currently utilizing the Next-Generation Wireless Communication (NGWC), also known as the wireless sensor network (WSN), sponsored by the U.S. Army Logistics Innovation Agency (LIA), in overseas logistics operations for the tracking and monitoring of military supplies and equipment [16]. Monitoring friendly soldiers, equipment, and ammunition allows commanders to continuously keep track of the status of friendly troops and the availability, condition, and condition of equipment and ammunition on a battlefield [17, 18]. In comparison to other tags, NGWC offers a far wider coverage area (a twenty-mile radius), faster data transfer rates, and stronger levels of security. The limitations of this technology include low energy communication networks, a lack of storage or computational power, latency, and scalability.

Figure2. Imagesofmilitaryapplicationsofwirelesssensornetworks[17,18]

According to the Institute of Electrical and Electronic Engineers' (IEEE) definition of LWID (Long Wavelength ID), RuBee is the approved commercial name for this technology [20]. RuBee technology offers visibility, providing more data than just product tracking. This technology offers long battery life, a wider read range, improved read accuracy, and the ability to read in challenging environments (such as water or metal) [21]. The RuBee Weapon Shot Counter, a novel weapons maintenance system that remotely maintains, diagnoses, and tracks weapons and munitions, has been created by the U.S. Navy in collaboration with Lockheed Martin and visible assets inc., saving it millions of dollars [22]. An integrated model for the Canadian Armed Forces' (CAF) supply network's asset visibility, tracking, and monitoringput out by [23]. The slower read rates of this technology, however, make it unsuitable for supply chain networks. Figure 3 shows an image of various RuBee tags, and Table 1 lists the limitations of these technologies in general.



3. The Digital Twin Concept

Grieves, 2014 [24] first the idea of a digital twin in the context of product lifecycle management in 2003 at the University of Michigan. After that, NASA created the first operational Digital twin in 2011 by simulating and analyzing digital models of aircraft to predict their structural behaviors (see Figure 4). A digital twin connects the physical and digital worlds and, through an interface, provides knowledge about a process's past, present, and future states. It does this by fusing data and intelligence. Real-time data can be used by the digital twin to perform simulations, optimize processes, and predict potential consequences [25]. In the digital context, these forecasts can be made more frequently thanwith the capacity to test scenarios by changing parameter values in the real world [7].

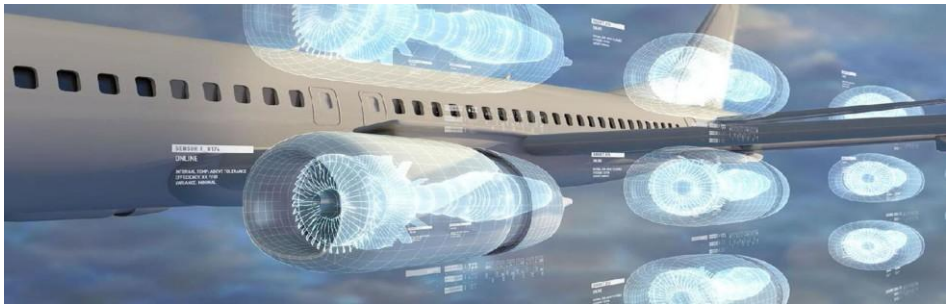


Figure4.Visualizationofdigitaltwininanaircraft[9]

4. Benefits of digital twin for military supply chain visibility

Adopting improved end-to-end visibility is one of the steps the military may take to secure their supply chains and enhance forecasting in all circumstances. This can be done by developing a digital twin that can see possible supply-side interruptions. Technology Restriction Devices for Radio Frequency Identification technical dangers, privacy concerns with barcodes, patency issues, infrastructural issues, and difficulties with the transition from barcode to RFID New Wireless Connection Technology Low-energy communication infrastructure, compute capacity or storage, latency, and scalability Technology from RuBee It is not ideal for supply chain networks due to the slower read rates. Digital twins are being used by S. Sani et al. in their study, "Utilizing Digital Twins for Increasing Military Supply Chain Visibility," to enhance decision-making. The digital twin technology is one of the next tools employed by the military and itsolutions that improve quality and efficiency while being cost-effective [7]. In agreement,[26] believed that the use of the digital twin gives military operations a sense of readiness in terms of tracking essential supplies (food, water, and fuel) in real time as well as personnel, equipment, and weapons systems. The US military has likewise made an effort to safeguard the integrity of its semiconductors' supply chain by adopting digital twin technology [27].

5. Enabling technologies of digital twin for supply chain visibility

5.1. Internet of things (IOT)

The Internet of Things (IoT) is the networking of physical items for the goal of enabling embedded systems for human-device or device-to-device communication [28]. Through sensors, devices with the necessary data can communicate with one another [29]. These sensors allow the digital twin to analyze and evaluate the physical twin that already exists [25]. In MSC, end-to-end asset visibility is made possible by the IoT, which also makes sure that supplies are delivered on time and at the correct location. This aids decision-makers by providing accurate and current information on the whereabouts and state of essential military supplies (food, fuel, weapons, gear, and spare parts).

5.2. Machine learning

A computer system called machine learning, which combines statistical and computer science components, automatically enhances its performance over time [29]. Machine learning's design can provide a digital twin that can use real-time data for analysis and decision-making utilizing predictive analytics.

5.3. Cloud computing

Through the usage of the internet and cloud computing, members of a shared network can use computer resources that are owned by a third party and maintained there. Data storage, databases, computing power, and processing for data analytics are a few of these resources [30]. The advantage of cloud computing is that users only need to pay for the services they use rather than having a lot of storage in their hardware [30].

5.4. Application programming interface (API)

Applications like databases, networks, and IoT devices can communicate with one another through APIs. Data can be effectively transported across clouds, devices, and other systems as a result. Public API connections, however, raise security issues, as demonstrated by the theft of Facebook accounts in 2015 that were connected to specific phone numbers [31].

5.5. Augmented and virtual reality

While augmented reality adds information to the real world, virtual reality uses technology to create a virtual world that mimics the real one. Through the use of a 2D or 3D screen, these technologies can offer a platform for seeing and inspecting the digital twin. For the purpose of constructing a digital twin, the data provided and processed by IoT, cloud computing, APIs, and machine learning can be visualized in augmented and virtual reality [32, 33]. Figure 5 displays the digital twin's enabling technology.

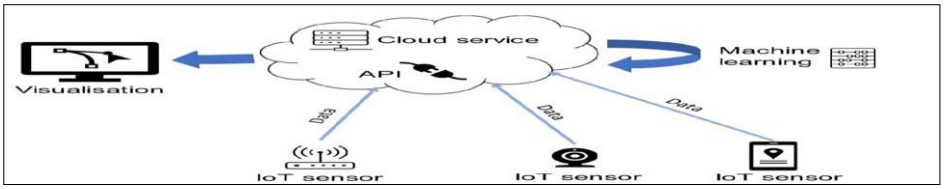


Figure5.Enablingtechnologiesofthedigitaltwin[32]

6.Implementation and application of the digital twin for visibility in the militarysupply chain

A digital SC twin can help with data-based decision-making regarding the physical SC. The digitaltwin can be utilized for planning and real-time control because it replicates the physical SC at every moment in time, including the actual transportation, inventory, demand, and capacity data [6]. The whole stack of technologies included by simulation, optimization, and data analytics can be used to build a SC digital twin, a model that consistently depicts the status of the network in real time as shown in Figure 6. The military uses the digital twin to test new models while building aircraft, predict equipment failures, speed up the production of weapons and aircraft, maintain gear, and help withmaking decisions in a hurry. The list of the numerous uses for digital twin in the military is included in Table 2 [34–38].

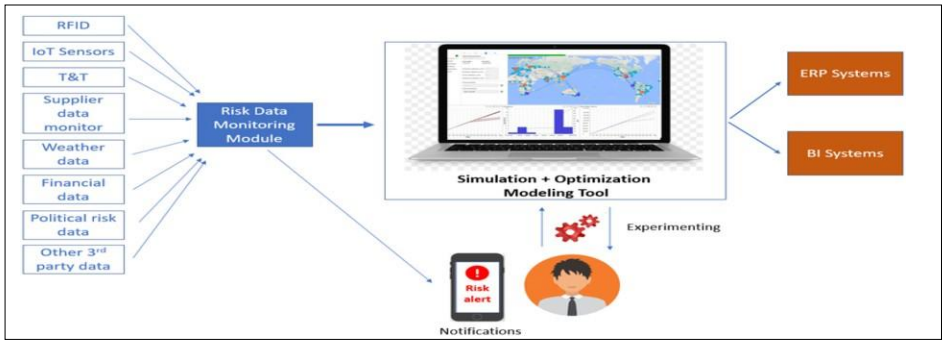


Figure6.Digital twinofsupplychain[6]

7. Conclusion and future work

The digital twin has enormous promise for ensuring complete supply chain visibility. A mirror of the current status or condition of the physical process, the digital twin is always up to date thanks to the utilization of real-time data. The visualization and analysis of processes can be aided by the digital twin, which is made possible by IOT, cloud computing, machine learning, APIs, augmented reality, and virtual reality. By building a digital twin to improve forecasting through end-to-end visibility, the military can safeguard its supply chains and ensure quick decision-making in the event of disruption. Although digital twin has a lot of potential, there is currently a lack of information in the literature on its actual use to achieve end-to-end visibility in the military.