Article Report & Analysis : *Industrial blockchain based framework for product lifecycle management in industry 4.0*

Course: Product Lifecycle Management
Students: `Gabriel CHAIX, Vincent COTTELA, Elvin CHA and Malo LEROY`

> **Link to the article:** Industrial blockchain based framework for product lifecycle management in industry 4.0 X.L. Liu, W.M. Wang, Hanyang Guo, Ali Vatankhah Barenji, Zhi Lia, George Q. Huang, 2020

1. Introduction

In a rapidly evolving industrial era defined by **interconnected machines**, **advanced analytics**, and **networked supply chains**, creating a seamless system to manage **every stage** in a product's lifecycle can be daunting. Traditional approaches typically rely on *centralized* databases and third-party vendors, often leading to bottlenecks, concerns about **data security**, and reluctance to share proprietary information across organizational boundaries. Yet, as **Industry 4.0** accelerates the push for open and intelligent manufacturing ecosystems, the need for a *trustworthy*, *decentralized*, and *transparent* PLM (Product Lifecycle Management) platform has grown ever more urgent.

Rather than depending on **one central repository**, the research article introduces an **industrial blockchain-based framework** designed specifically for PLM. This novel approach blends **blockchain technology**, **IoT (Internet of Things) devices**, and **M2M (machine-to-machine)** interactions to foster secure data exchange and **cooperative decision-making** among all stakeholders. By storing key product data in a shared, immutable ledger, companies gain confidence that every entry or update—from design sketches to final recycling procedures—is **verifiable**, **accurate**, and **protected**.

2. A Multi-Layer Blockchain-Based Architecture

As illustrated in fig.1, the proposed framework consists of five layers:

1. **Perception Layer**
    - **IoT devices**, sensors, and embedded systems collect real-time production and product usage data.
    - Raw data streams then move to the **Off-Chain Layer**.
2. **Off-Chain Layer**
    - Houses the **Blockchain Information Service (BIS)** that validates, cleans, and encrypts raw data.

- Prepares data for the **Blockchain Layer**.

3. **Blockchain Layer**
    - Runs a **pBFT-based algorithm** (a consortium-style consensus mechanism).
    - Ensures recorded data are **immutable** and **tamper-proof**.
4. **Application Layer**
    - Offers tools such as **CAD**, **CAE**, **MES**, etc.
    - Interfaces seamlessly with blockchain-validated data.
5. **Service Layer**
    - Provides functions for **co-creation**, **real-time tracking**, **proactive maintenance**, and **end-of-life recycling**.

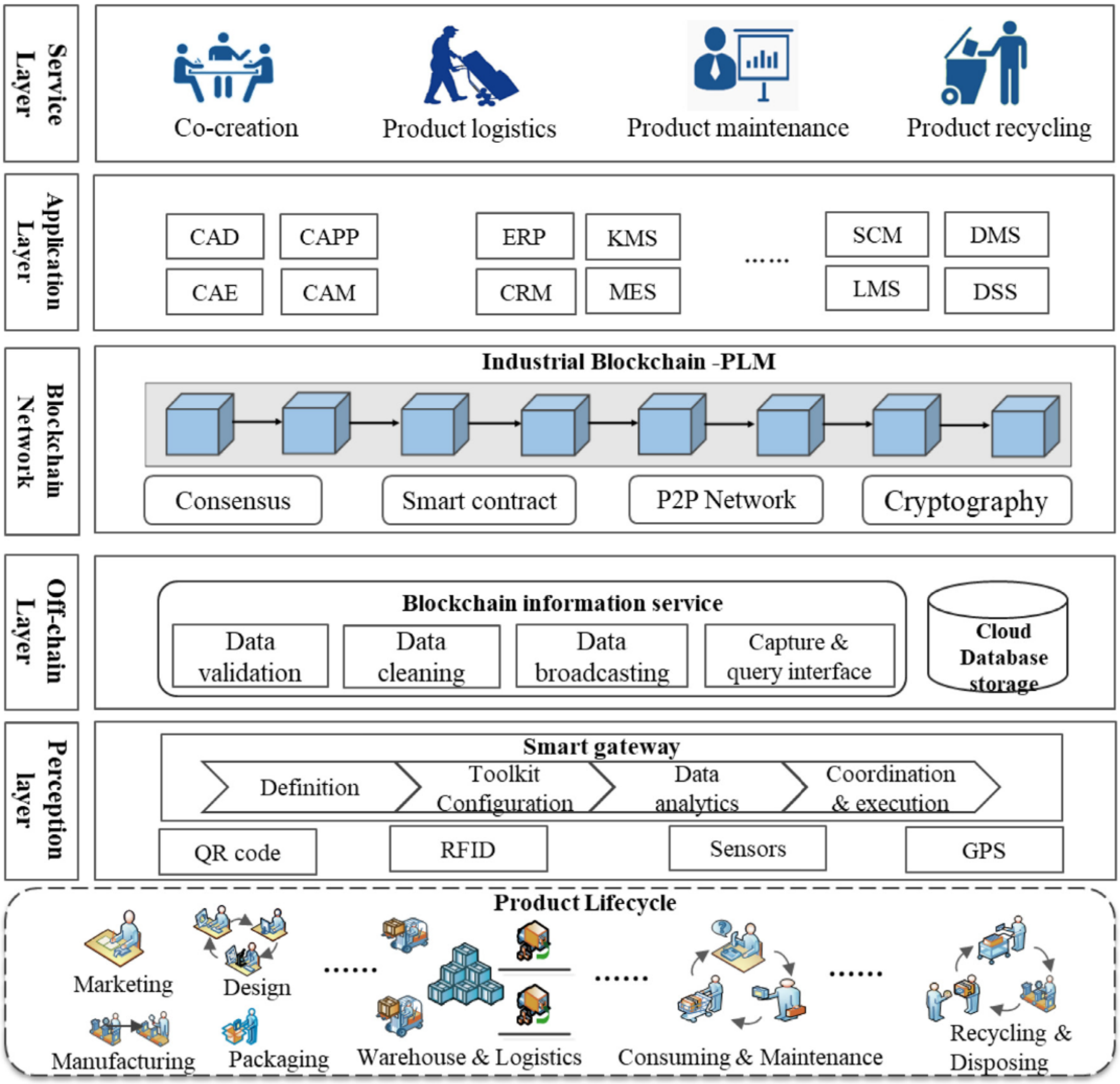

Fig. 1. The architecture of the proposed blockchain-based PLM.

These layers collectively ensure a smooth **data transfer** and **verification** pipeline. In the **Perception Layer**, for instance, data capture is continuous, while the **Blockchain Layer** guarantees that sensitive information is neither lost nor manipulated. The **Application Layer** then provides user-facing services, and the **Service Layer** bundles specialized operations.

3. Key Components and Mechanisms

3.1. Blockchain Information Service (BIS)

The **BIS** acts as a **central bridge** between enterprise systems and the blockchain itself. It:

- Receives high-volume, heterogeneous data from **internal databases**, **smart gateways**, or **IoT endpoints**.
- Converts large or private datasets into **hashed references**, placing only verifiable fingerprints on-chain.
- Ensures **multisource** and **heterogeneous** data are uniformly processed.

3.2. Consensus and Data Integrity

Once data are bundled into blocks, the platform's **consortium-style consensus algorithm** (pBFT) ensures that the ledger is kept consistent across **all participating nodes**. As depicted in

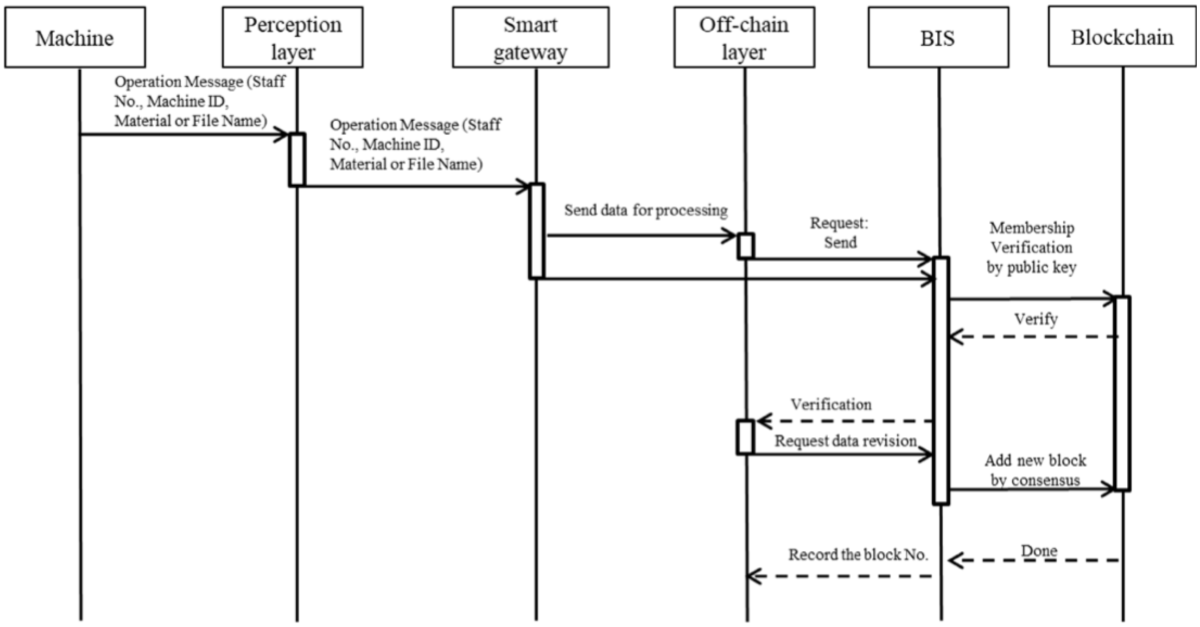

Fig. 2. The information flow from a machine-level to blockchain network.

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> Only valid and fully verified blocks become permanent records.

This **decentralized consensus** boosts trust among all parties and reduces reliance on external intermediaries.

3.3. Smart Contracts

Smart contracts power the **condition-based tasks** without human intervention. In this framework, they:

- Detect **real-time alerts** (for instance, if a temperature exceeds a threshold).
- Validate transactions automatically.
- Distribute design or maintenance data securely across stakeholders.

When certain IoT inputs trigger a rule, the smart contract automatically notifies relevant personnel or systems and records the resulting actions on the blockchain.

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4. Four Core Services Across the Product Lifecycle

To illustrate the practical value of the framework, the article explores four services that align with the beginning, middle, and end of a product's life, as shown in fig.3.

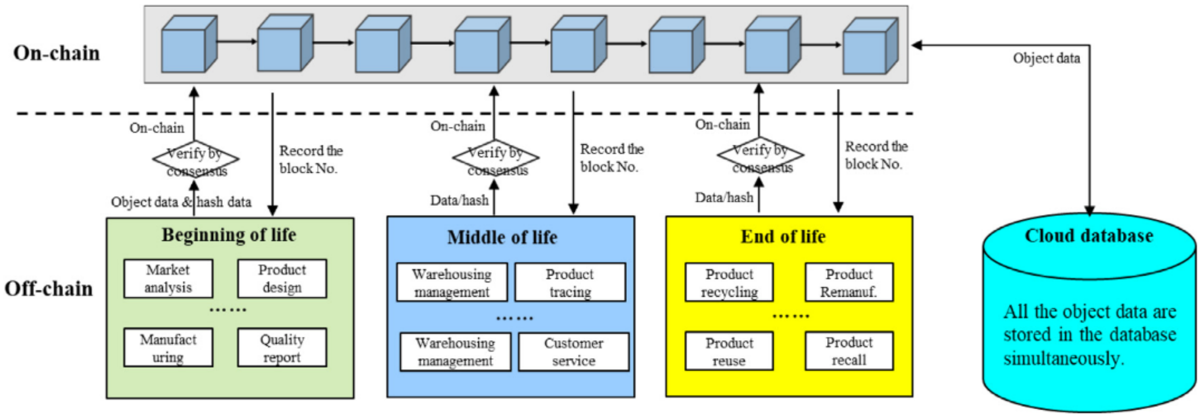

Fig. 3. Three stages of product lifecycles.

4.1. Co-Creation

During the design and manufacturing phases (Beginning of Life), participants such as consumers, designers, and multiple enterprises can securely collaborate on product requirements and feedback. Because only a cryptographic hash of the design file goes on-chain, sensitive intellectual property remains protected. Yet, the immutable record of who contributed each idea—and when—fosters transparency. Co-creation is thus greatly enhanced by heightened motivation and genuine involvement from external contributors here in fig.4.

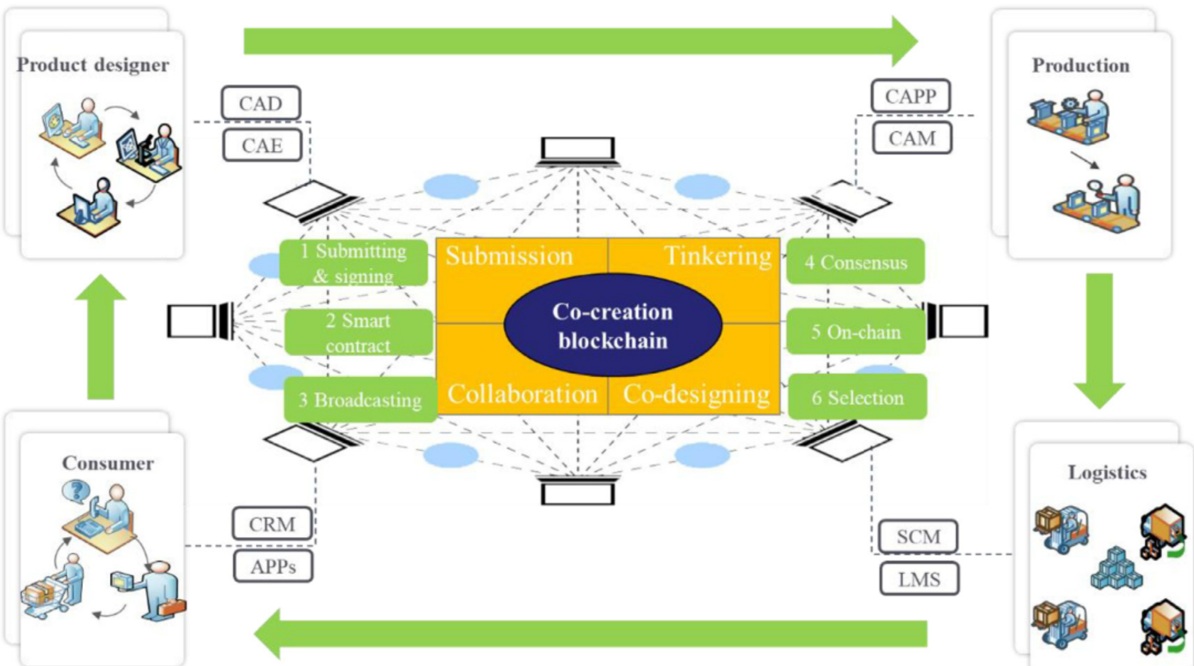

Fig. 4. The collaborative development based on co-creation blockchain.

4.2. Quick and Accurate Tracking and Tracing (QAT2)

Real-time data from logistics and warehousing are consolidated on the blockchain so that anyone with authorized access can examine a product's origin, location, and condition. This immediate insight into the supply chain (shown in fig.5)

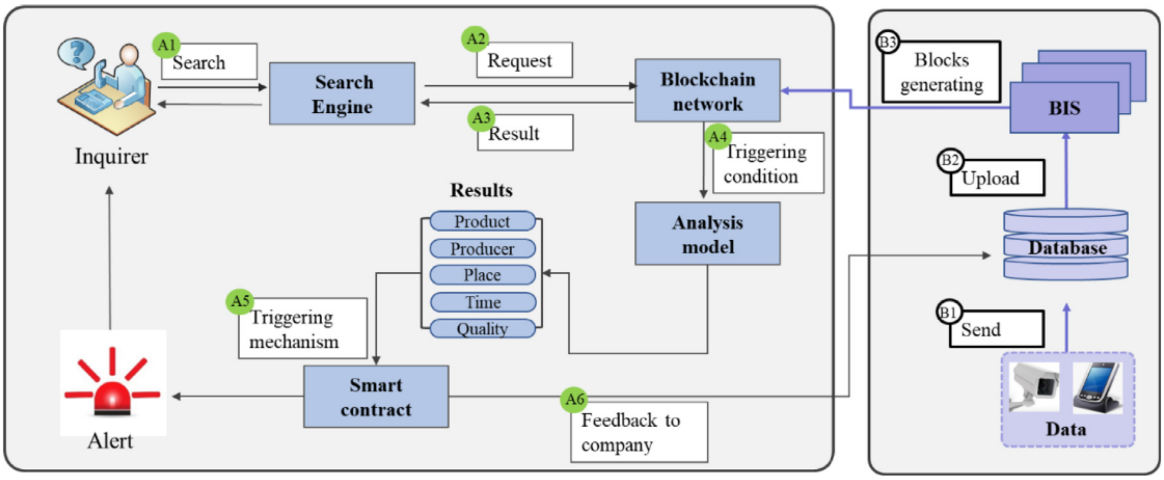

Fig. 5. Blockchain-enabled real-time tracking and tracing service.

helps assure compliance, reduce counterfeits, and ensure quick recalls if necessary.

4.3. Proactive Maintenance

Long after a product leaves the factory, IoT sensors gather performance data, which the BIS channels onto the chain. Smart contracts can then trigger predictive maintenance alerts if any anomalies are detected. As described in fig.6,

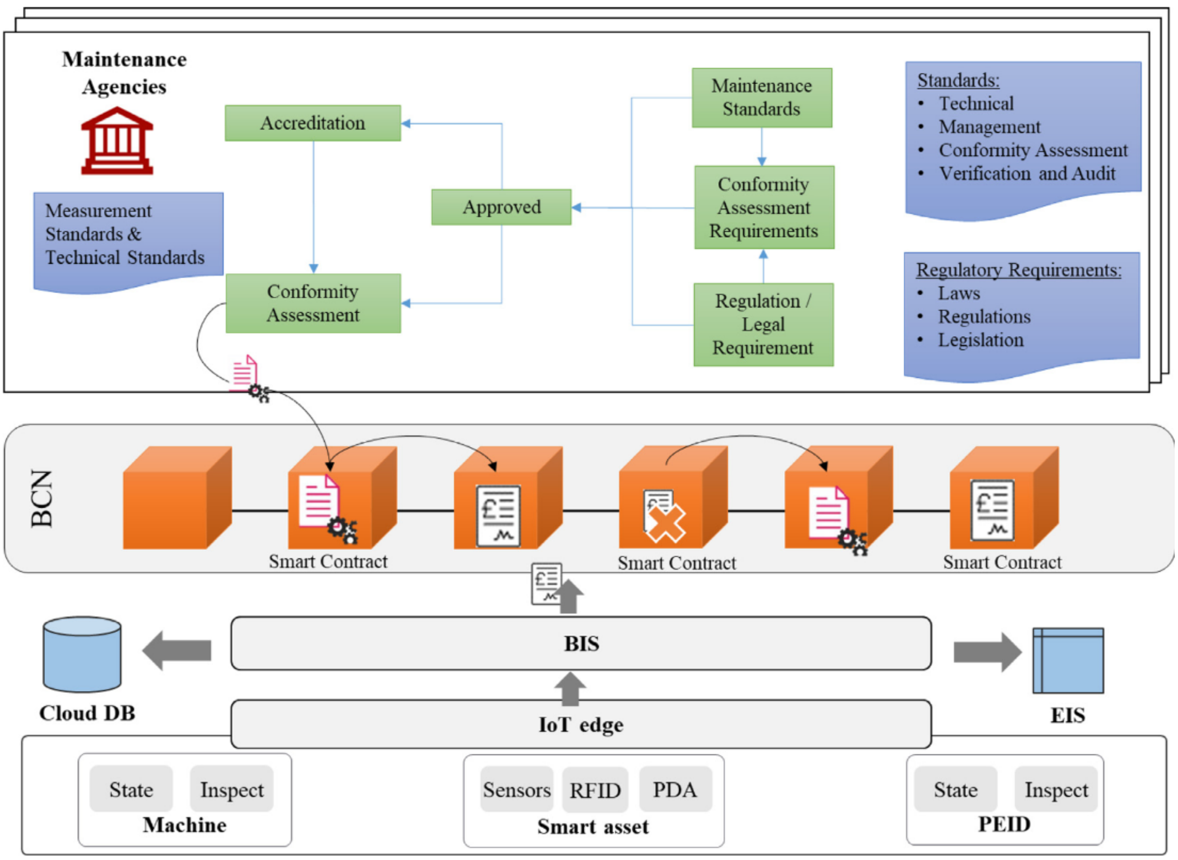

Fig. 6. Blockchain-enabled proactive maintenance service.

this arrangement minimizes unplanned downtime and ensures that each maintenance step is recorded for clear operational history.

4.4. Regulated Recycling

At the end-of-life stage, products can be returned and safely dismantled or refurbished. Each step—bidding, reclamation, and reprocessing—is not only transparent but also governed by established smart contracts (see fig.7).

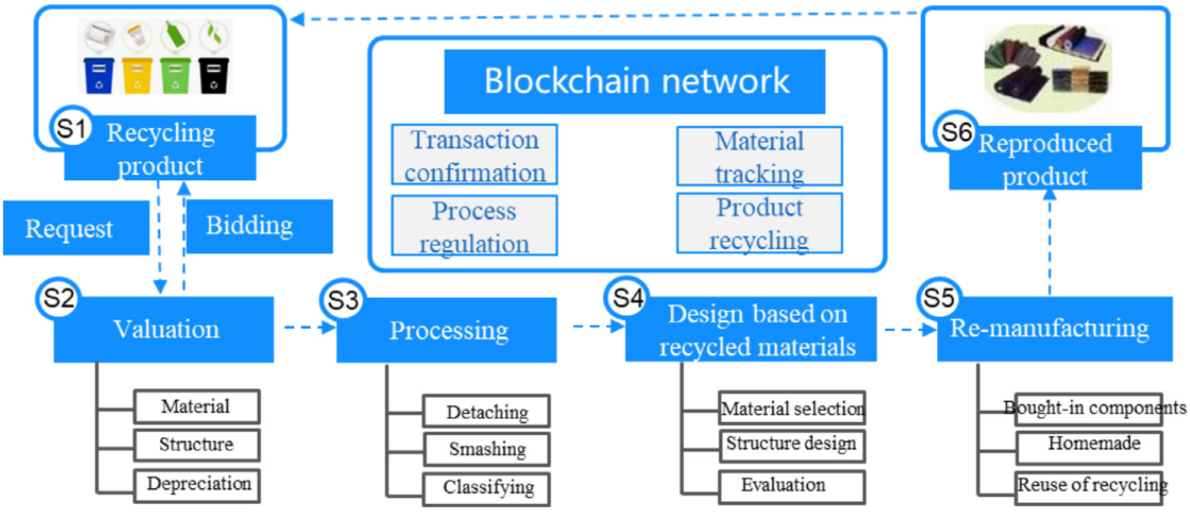

Fig. 7. The mechanism of recycling for design based on blockchain.

This chain-based history keeps materials out of landfills and helps manufacturers design more sustainable products in the future, knowing exactly how existing units were recycled or repurposed.

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5. Performance Insights and Comparisons

A pilot implementation was built using **Hyperledger Fabric** to gauge performance. When matched against a public blockchain like **Ethereum**:

- **Throughput**: *Higher* in a **consortium setup**, particularly as transactions scale.
- **Latency**: *Lower*, since fewer steps are required to reach consensus among known (permissioned) nodes.
- **Ethereum**: More decentralized but can slow down confirmations.

These findings show that a **Hyperledger-based** solution can manage increasing participants while remaining **efficient** and **secure**. The research also underscores the importance of integrating with existing enterprise software—such as **ERP** or **MES**—and outlines methods for **smart contract upgrades**.

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6. Conclusion

This **industrial blockchain-based PLM framework** marks a significant step toward a more **cooperative**, **transparent**, and **efficient** way of overseeing the full product lifecycle. Its multi-layer architecture, enriched by **IoT** and **M2M** connectivity, ushers in **decentralized consensus**, **automated smart contracts**, and **secure data exchange**.

- **Benefits**:
  - Manage **intellectual property** safely.
  - Maintain **high-quality** processes and rapid problem-solving.
  - Gain **improved interoperability** and **verifiable integrity** of data.
  - Encourage **sustainability** via regulated recycling and **circular economy** approaches.
- **Challenges**:
  - Scaling beyond pilot phases.
  - Handling **on-chain** vs. **off-chain** balance.
  - Ensuring **smart contract** versioning and governance.

Despite these challenges, this framework heralds a new era for **PLM in Industry 4.0**, where businesses can leverage blockchain to create an **immutable chain of trust**. By embracing a decentralized structure, organizations secure *not only* greater transparency and data integrity, but also pave the way for **sustainable** product loops and **collaborative innovation**.