More Transparency and Efficiency through Completely Digitalized Kanban-Based Value Chains

Whitepaper

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More Transparency and Efficiency through Completely Digitalized Kanban-Based Value Chains

How Intelligent Sensor Fusion Combined with Cloud-Based Applications Supports Modern and Lean Production Control

Abstract

Lean production methods are now standard in almost all modern manufacturing companies. As a pull-based production process control system, KANBAN is based exclusively on the actual demand for materials and products at the point of use, enabling optimal control of the flow of goods. The current industry standard for implementing a Kanban system ranges from the manual transportation of paper cards to the reading of barcodes and detection using RFID-based systems. Although partially digitalized solutions already solve some of the problems of analog systems, they still almost always involve manual scanning. This article shows how complete digitalization of the Kanban process can increase the transparency and quality of the value chain, reduce replenishment lead times and tied-up capital, and further increase production efficiency. It explains a solution involving the intelligent sensor fusion of optical rails in Kanban racks and RFID systems at different stations in production and describes how the solution interacts with a modern cloud-based application. The outlook discusses how this solution incorporates the concepts of Industry 4.0 and the advantages that this type of implementation will bring to future production.

Introduction

From Paper Cards and RFID to a Fully Digitalized Process

In line with the just-in-time concept of lean production, Kanban is now a widely used subsystem for controlling the flow of materials and information on the shop floor. This is designed to optimize the cost of production by reducing stock levels and the associated capital tied up in materials. Other aims include short lead times, guaranteed adherence to deadlines, and more flexibility when demand changes.

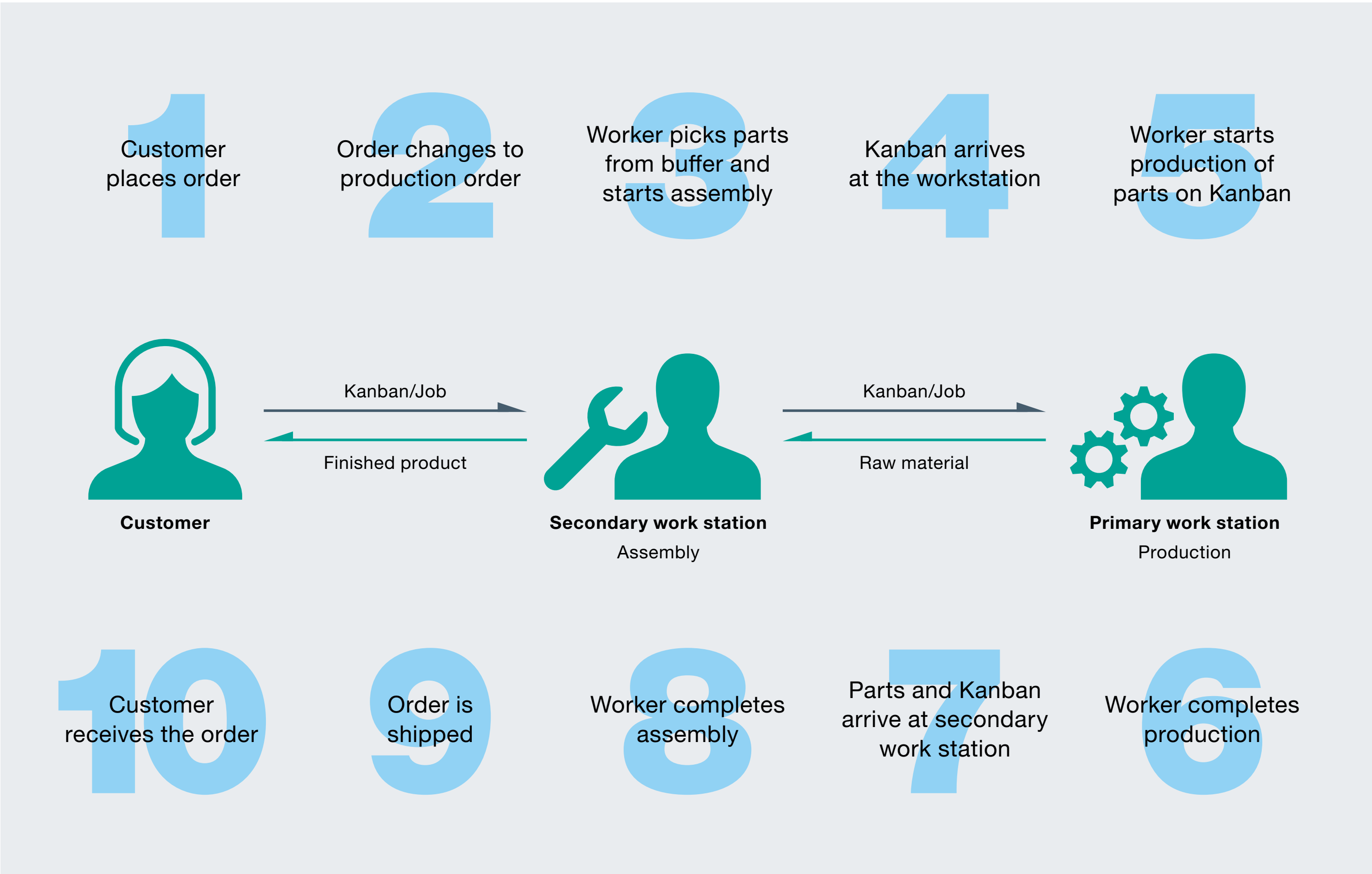
In the original implementation method, paper-based Kanban cards circulate between the different stations of the production value chain. This chain is divided into self-governed control loops, which are supplied according to the supermarket principle (see a simplified depiction of the Kanban principle in the graphic below).

Consumption and thus the signaling of demand at a station triggers upstream processes. This kind of pull-based control system is based exclusively on the actual demand for materials and thus directly supports the cost-optimized control of the flow of goods.

The Kanban cards are usually attached to containers that contain raw or other materials. If the contents of the small load carrier have been used up, the worker must report the demand to the upstream workstation. There, a new container is picked according to the Kanban card and transferred to a supply train (milk run).

There must be sufficient material at the production unit while the replenishment process is underway to ensure that continuity of production is not jeopardized. This means that the replenishment lead time in a control cycle is one of the most relevant parameters for Kanban-based process control. It directly influences the quantity of material required to ensure continuous production.

Logically, the replenishment lead time in the purely manual Kanban system is high. This is because “ordering,” i.e., the transportation of the Kanban card to the upstream process station, is performed manually in addition to the actual delivery of raw materials to the production unit. Because of this, there is little transparency regarding material consumption at the process level, since there is usually a delay in recording used Kanban materials in the IT system.



How the Kanban principle works [1]

Furthermore, very little information on the current status of the order is available. Orders are either not started or already completed. The next logical development is a Kanban control loop based on barcode or RFID read heads. With this technology, empty small load carriers are recorded as “empty” in the system based on a manual scan by the worker.

In such solutions, called e-Kanban, the replenishment lead time is reduced by the time it usually takes for a card to reach the upstream station. However, the reliability of this process depends heavily on the diligence of the workers. If they wait until the end of their shift to record all of the cards as used or forget to record their status altogether, this creates a discrepancy between reality and the ERP (Enterprise Resource Planning). At worst, this can lead to excessive buffers, an inaccurate virtual inventory, and, ultimately, incorrect orders.

Although this solution offers greater transparency than paper-card-based procedures, supermarket racks in production supply areas (PSAs) are still not transparent. The system shows that material should be available in such PSAs, but it does not specify where or if there are any incorrect entries. Furthermore, the assignment of Kanban control loops to tracks must be relatively rigid, with little flexibility. In turn, this can lead to wasted space in the PSA, for example, if only very few small load carriers with parts for “low runner” products are present on one track.

Complete end-to-end digitalization of the Kanban process along the entire production value chain, including all racks in warehouses and PSAs, makes the Kanban-controlled material flow in production deeply transparent. By combining different sensors for identification and localization with modern process-oriented software, time-consuming and error-prone manual recording of statuses can be eliminated. Inventory changes, such as the depositing and removal of small load carriers, are guided by put-to-light and pick-to-light signals and detected as an event by sensors. This prevents status recording errors on the rack and means that Kanban card statuses can be changed automatically (e.g., from “in transit” to “in PSA, track S.1.2”).

Automated event detection eliminates manual scans for reordering and reduces the replenishment lead time. Employees can focus fully on value-adding tasks and are assisted in maintaining optimal process quality. In addition, transparency regarding rack stock, proper synchronization between the system inventory and reality, and real-time reconciliation of material and information flow make it possible to minimize buffer stock in PSAs. By adjusting production planning accordingly, it is possible to create dynamic and flexible track configurations in racks and save valuable space and unnecessary capital. Moreover, a continuously transparent Kanban process facilitates milk run optimization, from regular filling runs to precise, demand-based control.

Concept

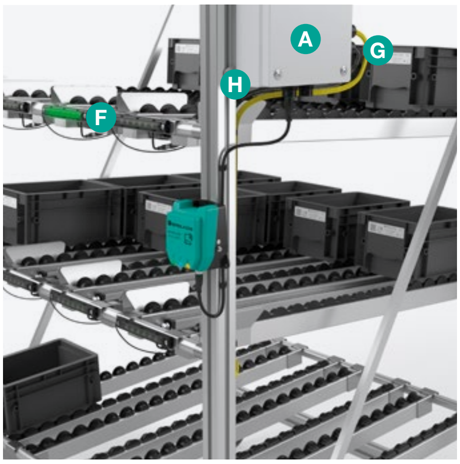
How Distributed Sensors Harmonize with Modern Process-Oriented Cloud Software

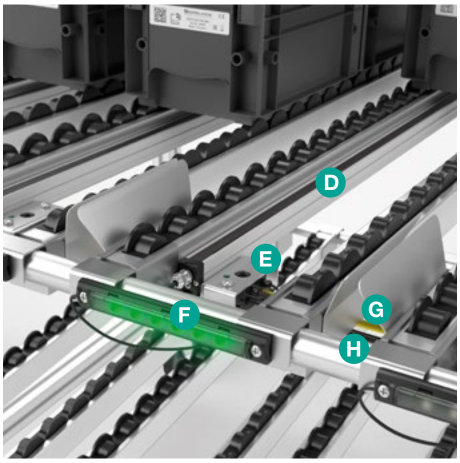
The existing concept digitalizes the Kanban process using an intelligent combination of RFID systems for identification, a sensor rail consisting of photoelectronic triangulation sensors with background suppression for the precise localization and recording of material movements on racks, and modern cloud software. To identify the Kanban cards, RFID read heads are installed at all points in the process where work steps that affect the flow of materials are carried out. RFID wristbands can be used for easy detection of RFID tags in the motion sequence. All racks in interim storage areas and production supply areas organized using Kanban detect and intelligently process material movements using a combination of RFID read heads, sensor rails, and the associated peripheral components.

These components are shown installed in the rack in the pictures below and marked with the letters A to H. The corresponding table explains which components the letters refer to. The graphic on the next page provides an overview of all system components shown without rack hardware. This should make the explanation clearer. The functions of the individual components are briefly described below.

The **main controller** is a central intelligent unit and is responsible for aggregating the local sensor data, processing the data, activating pick-to-light and put-to-light LEDs, and operating the status light.

A Main Controller
B Power Supply (not visible)
C Signal Light
D Sensor Bar
E Rack Controller
F Display Module
G Data Communication Cable (yellow)
H Power Supply Cable (black)





CAD model of a digitalized Kanban rack [2]

The **power supply** supplies the main controller, the signal light, and the AS-Interface cable for the bus power supply.

The **signal light** indicates that the system is operating correctly and shows any fault states. This allows the operator to quickly identify a faulty configuration, problems connecting to higher-level systems, and errors in the current inventory.

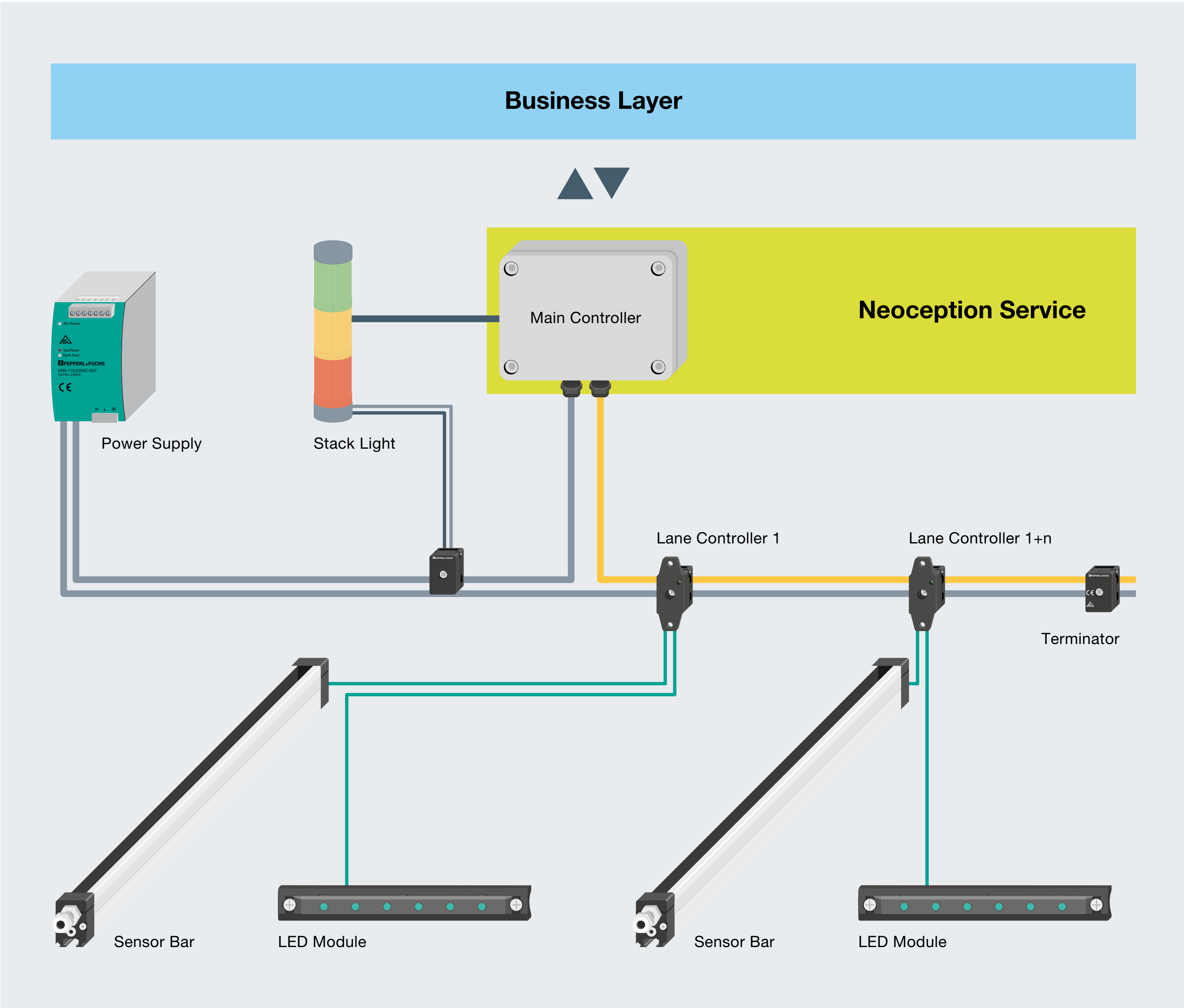
On each track, a **sensor rail**, **rack controller**, and **LED (display module)** are connected with piercing technology via the terminal connections typical for AS-Interface. This connection allows a flexible response to different distances between the tracks in the rack. Up to 50 tracks can be connected to a single main controller.

Since all components are user-friendly and easy to install, continuous digitalization of the material flow can be both integrated into an initial design for greenfield production systems and retrofitted in existing logistics infrastructures. A retrofit can therefore turn a manual Kanban workflow into a digital map to improve transparency and efficiency.

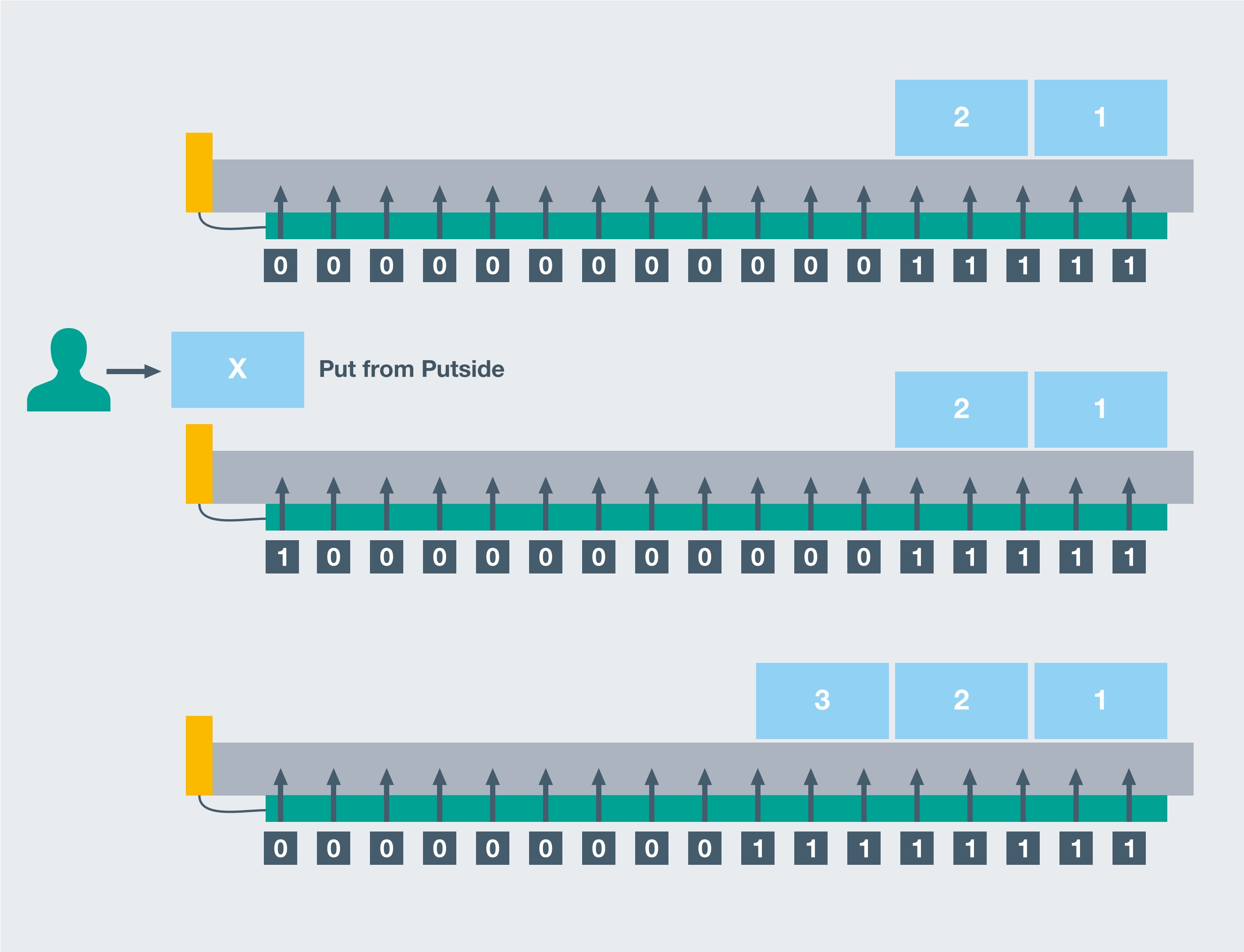
Using the sensor rails specially developed for Kanban racks, it is possible to detect all movements that change the stock on the shelf, such as filling and removing small load carriers on both sides.

Intelligent evaluation of the sensor data allows the correct interpretation of process-relevant events. Visual signals are collected from the sensor rails, which are available in different lengths, and transferred to the locally implemented part of the Kanban software as a continuous data stream. This software interprets the data stream from the rails using pattern recognition based on complex rules.

Any movement on the shelf can therefore be detected and interpreted logically. For example, if a sensor is accidentally briefly covered by someone's hand, this is filtered out and largely ignored. The consistent registration of events in the cloud-side back-end of the software provides a correct and synchronized digital map of the rack stock at all times.



System overview of the digitalization components of a Kanban rack [2]



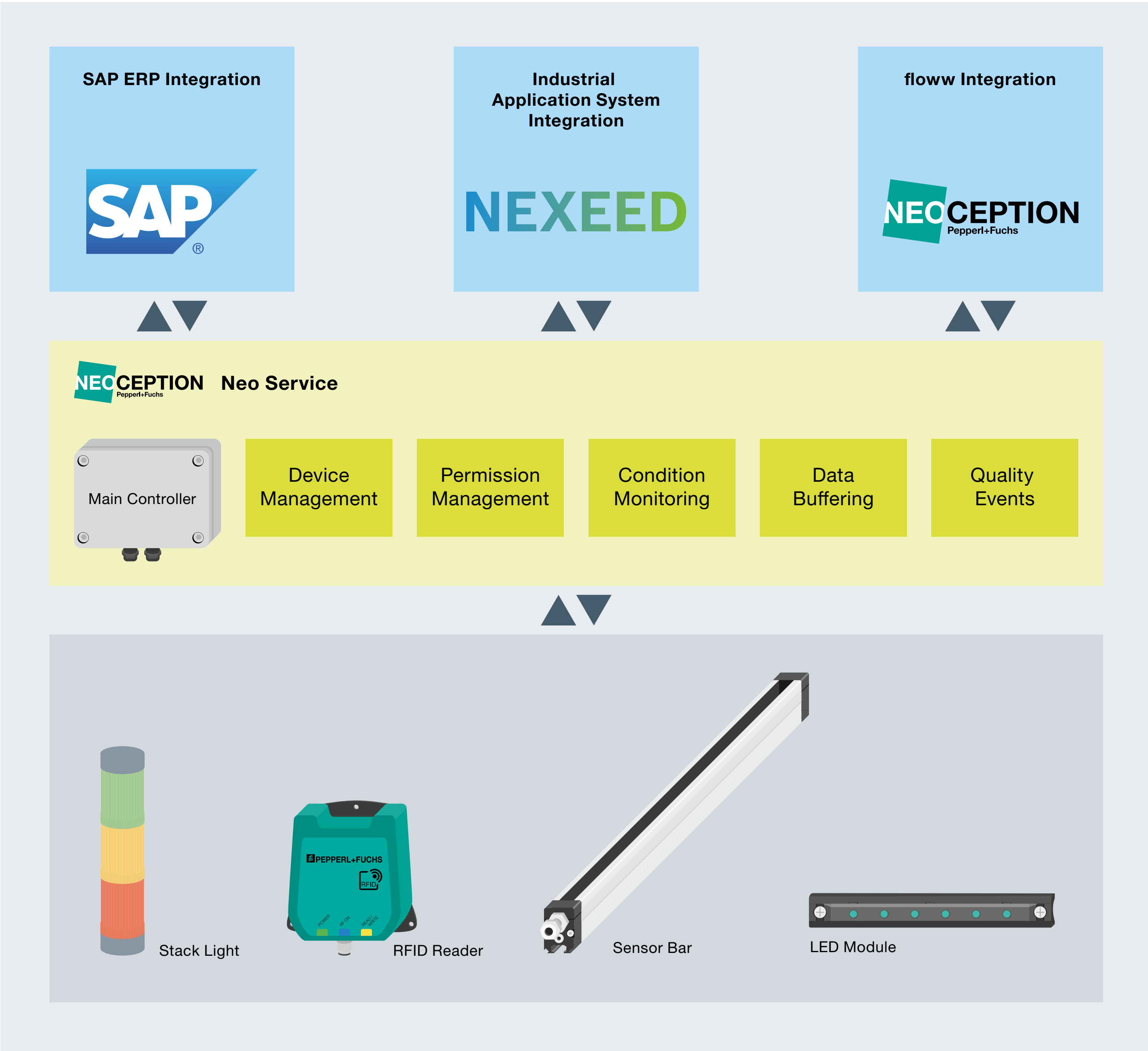
Pattern detection when filling a digitalized Kanban rack

The graphic on this page is an abstract depiction of how the sensor data from the triangulation sensors with background suppression creates patterns that can be evaluated over time to provide information about material movement. The displayed pattern (with intermediate steps not shown here) would be correctly interpreted as filling taking place on the filling side of the rack. The availability of cleared process events, which is important for efficient control of replenishment, is thus provided in real time. When a load carrier is removed from a track, its replenishment can be requested immediately—without manual scanning.

In addition to the local hardware and software components, a central Kanban management service with various subcomponents is part of the presented digitalization solution. This service is designed as cloud software and is used for easy management, orchestration, and monitoring of all hardware components, and, depending on the integration scenario, also for easy configuration and control of the Kanban process.

The graphic here shows a rough overview of the hardware and software components involved in digitalization on the Kanban rack.

This service provides functionalities such as device and permission management for the local components and monitors, for example, the status of sensors and gateways in the field. Among other things, it is possible to respond quickly if components do not work as intended. In addition, buffers can be implemented between process events to prevent unnecessary interactions with ERP and warehouse management systems (WMS) and to limit them to a healthy level. This service layer also supports lean and customized integration into different business software, such as the Bosch Intralogistic Execution system and SAP ERP systems. In very lean designs, a standalone system with or without customer-specific integration can also be integrated into other existing planning systems.



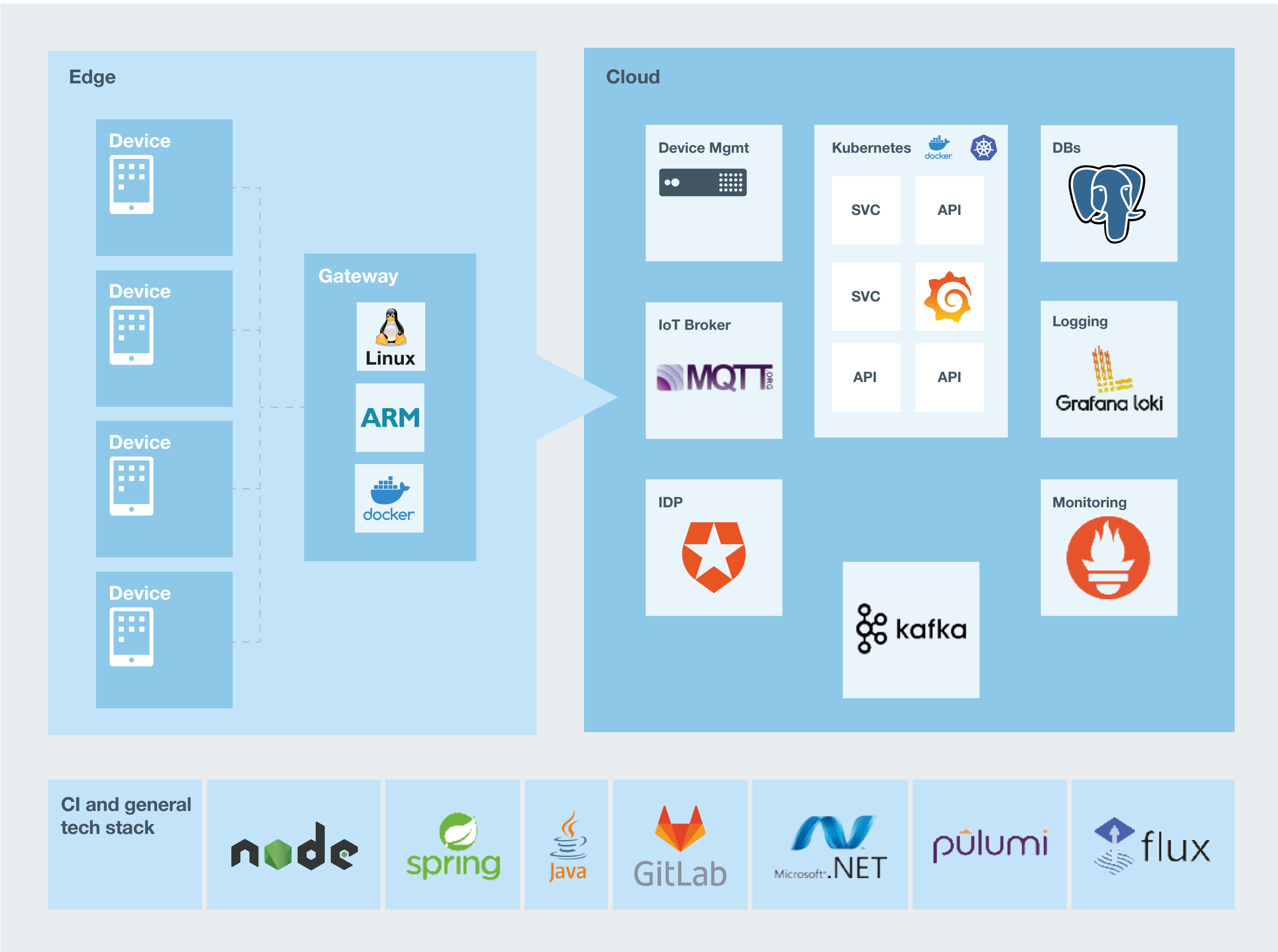
Overview of the hardware and software components involved in complete digitalization of Kanban racks

To address the benefits of the implementation as cloud software in more detail, the image below shows a schematic overview of all the technologies used and their application areas. Running the cloud service as a modern microservices architecture takes advantage of several benefits [3].

First, applications based on distributed services are highly available, which is essential in the production control environment. In addition, they enable fast horizontal scaling in the event of load increases. Since all services in the cloud are available with web UIs, software installations on devices become obsolete and updates are implemented more quickly. A high degree of automation across all applications, including the actual infrastructure, allows for good reproducibility of the exact system, making it easy to create additional environments for testing, different configurations, other facilities, and more.

The conventional IoT world—i.e., the connection of sensor technology to cloud services—is realized via individual edge gateways with secure elements for cryptographic identity and password-free authentication. This minimizes the vulnerability of the gateway's basic operating system. All services are rolled out as largely immutable docker images—both edge- and cloud-side. Permissions are limited to containers; all containers are monitored in real time. An event-based architecture with Kafka as a central message broker allows quick and easy customization, application extensions, and various uses of clean and secure events for downstream services without loss of performance (e.g., central raw data acquisition and direct processing to business events).

This short technological digression should show that the presented, complete digitalization concept of Kanban processes based on cloud software not only brings many advantages for the application itself, but also incorporates and implements the core concepts of Industry 4.0.



Overview of all technologies used in the cloud solution with their respective application areas

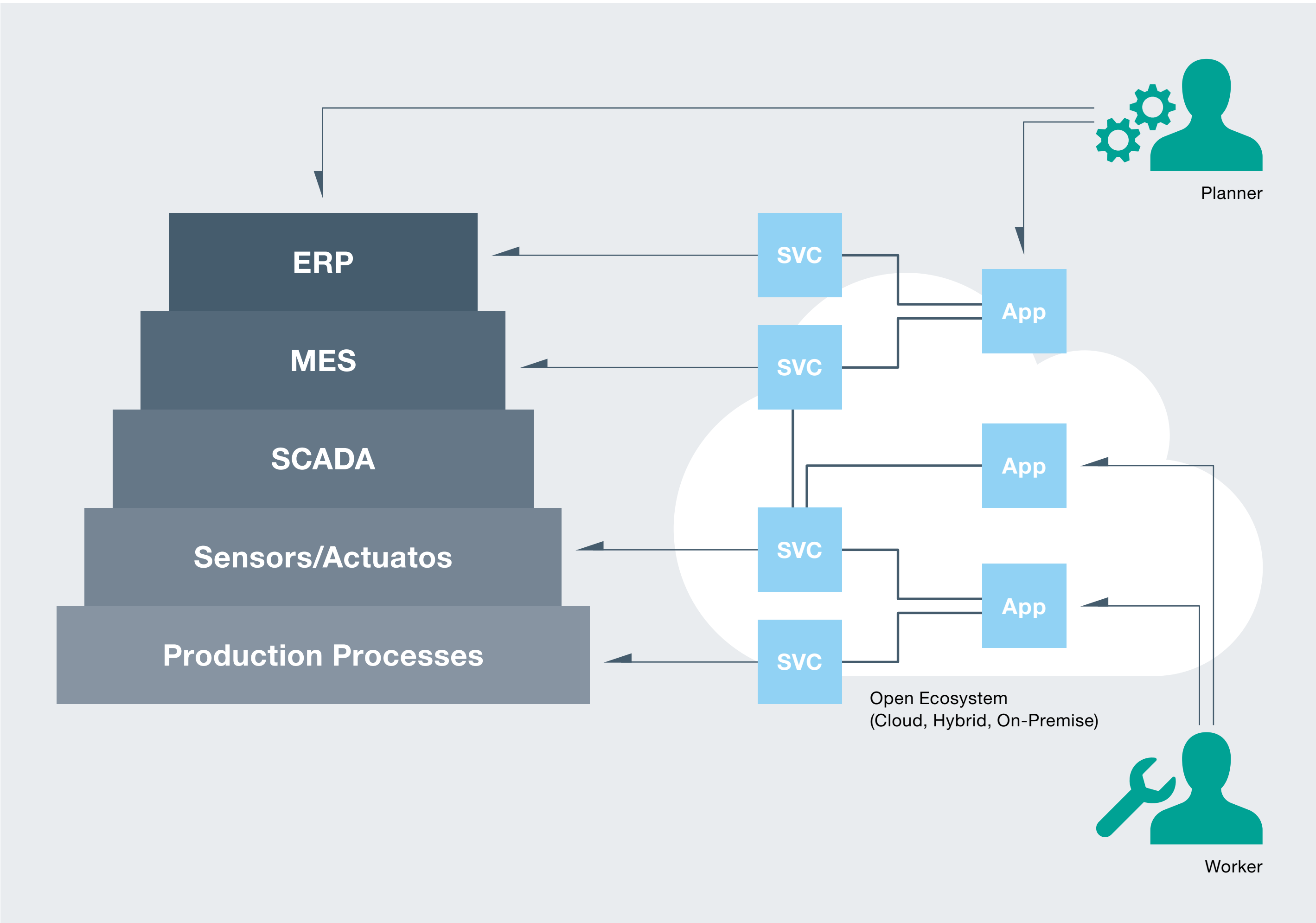
Outlook

A Fully Digital Kanban Process for Industry 4.0

The presented end-to-end digitalization of Kanban-based value chains boosts the transparency and efficiency of the process, as described in sections 1 and 2. The service-oriented application itself is functional, value-creating, and scalable. The advantage of this type of implementation is that it is easily used in parallel with the conventional automation pyramid without having to engage with it. Existing ERP, MES, and WMS systems are thus supplemented with functionalities that have direct access to data from the sensor and process levels. This information transparency across the various levels of automation is considered one of the core organizational principles of a fourth industrial revolution.

In general, current scientific descriptions predict future production systems that are largely linked to an open ecosystem of different applications and services [5].

The graphic shows an open ecosystem that exists in parallel to the conventional automation pyramid and where applications exchange data across hierarchy levels. This level of interoperability can be achieved through standardized interfaces between the individual services. The method described here for implementing completely digitalized Kanban-based value chains by combining various sensors and modern cloud-based and service-oriented software takes into account these principles of Industry 4.0 and is already laying the foundation for future, leaner and more flexible production IT systems.



Digitalization and microservices architecture as a future-proof concept [4]

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Product Owner
Neoception GmbH

Neoception Digital Services

An industrial plant automatically notifies its manufacturer when it reaches a certain number of operating hours. The need for wear parts is recognized, and the operator automatically receives a corresponding delivery. This additional service increases plant availability and makes maintenance and service processes more efficient. Well-designed, end-to-end digitalization generates added value for both manufacturers and operators.

Neoception GmbH is your partner on the path to value-added digitalization. We support you—as manufacturer or operator—in your pursuit of Industry 4.0, whether for the connection your products and plants to central data services or the data-driven optimization of your internal production and logistics processes.

- Have you always wanted to learn more about your products in the field to better serve your customers?
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True to the motto "Think digital, add value", we are your partner of choice for digital value-added services within the Pepperl+Fuchs Group and beyond.

For more information,
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