



DIGITAL MEET MANUFACTURING



Industry 4.0
Dictionary

3G 3rd Generation

Mobile communications technology which among others includes the UMTS standard.

4G 4th Generation

Mobile communications that goes beyond 3G and is chiefly meant for ultra-broadband Internet connection with speeds of 100 megabit per second to mobile users.

4IR 4th Industrial Revolution

Fourth Industrial Revolution is the fourth major industrial era since the initial Industrial Revolution of the 18th century. The Fourth Industrial Revolution is described as a range of new technologies that are fusing the physical, digital and biological worlds, and impacting all disciplines, economies, and industries.

5G 5th Generation

5th generation mobile networks or 5th generation wireless systems, abbreviated 5G, are the proposed next telecommunications standards beyond the current 4G/IMT-Advanced standards, operating in the millimetre wave bands.

Access Control

Access Control means to ensure that access to assets is authorized and restricted based on business and security requirements.

Note: Access control requires both authentication and authorization.

Accuracy

A measure of how precisely a sensor reports the signal. For example, when the water content is 52 percent, a sensor that reports 52.1 percent is more accurate than one that reports it as 51.5 percent.

Actively Declared Data

Data that consumers hand over voluntarily about themselves – for instance, when registering for services, declaring public records, buying products, requesting quotes, participating in surveys or entering competitions.

Activity

Specified coordination of tasks that are required to realize the system capabilities.

Note: an activity may be composed of other activities.

AM Additive Manufacturing

Manufacture of a solid body by depositing successive thin layers of material, usually powder, until the desired shape and size are obtained (also called 3D Printing). It has extensive applications in the industrial world and represents a revolution in manufacturing processes and systems.

Administration Shell

Virtual digital and active representation of an I4.0 component in the I4.0 system.

Note 1: An administration shell contains the manifest and the component manager.

Note 2: administration shell is synonym to asset administration shell (AAS).

AES **Advanced Encryption Standard**

Advanced Encryption Standard, a specification for the encryption of electronic data. Advanced Encryption Standard process, the process used in choosing an algorithm for standardization. AES instruction set, an x86 microprocessor architecture addition to accelerate Advanced Encryption Standard.

AM **Advanced Manufacturing**

This is the somewhat more general name used in the world, since it was coined by the government of the United States, than Industry 4.0, which is of German origin. In addition to the technologies involved in the digital transformation for Industry 4.0 (additive manufacturing, collaborative robotics, cyber-physical systems, augmented reality, cloud computing, big data, computer vision, artificial reality and cyber security), the American definition also refers to the use of new avant-garde materials and emerging capabilities enabled by the biosciences and nanotechnology.

Advanced Research Computing

High performance computing and storage needs that are too complex to be handled by a standard desktop workstation, specifically in support of research. Includes cloud environments, massive-scale infrastructure and large computational power.

Algorithm

Formal specifications used in software to process and analyse datasets. Typically made up of a series of calculation steps, an algorithm will describe how to process data with the goal of solving a specific problem.

Analysis Patterns

Works with domain knowledge, such as object models (Ontologies) and data models (entities and attributes).

Analytics

The process of using statistics, algorithms and software to transform data into useful information and to draw conclusions.

Anonymous Data

Information that is collected or used without any personal identifiers and where identification is unlikely to take place.

App Store

New capabilities on demand. Intelligent digital forms or complete applications, such as those familiar today from well-known app stores for smartphones, tablets or computers, and which endow robots with new capabilities and functions on demand at the click of a mouse. For example, programs that only require entry of the desired parameters. With regard to Industrie 4.0, the immediate availability of new production capabilities will open up a whole new dimension of versatility for robots.

Application

Self-contained software programs that fulfil a particular purpose or enable a user to perform a task.

Application Architecture

Application integration architecture refers to the standards and policies created to define the means by which manufacturing and engineering applications are built, accessed, and integrated across the 4IR enterprise. It consists of a set of application guidelines and architectural components, and may include messaging standards for accessing applications. This standardization is expected to enhance the organization's ability to extract data from applications (and hence value), link disparate business and manufacturing processes, and ultimately eliminate redundancy between applications across the 4IR enterprise.

Application Domain

Collection of functions implementing application logic that realizes specific business functionalities.

Application Layer

This includes the protocols and interfaces that devices use to identify and communicate with each other.

API Application Programming Interface

One way for an application to present itself to other, typically remote, applications so that they can interact with it (for example, to read or write data to it). Often now used as another term for a Web Service.

ArchiMate

An Open Group Architecture Framework - a widely used framework that includes a notation for visualizing architecture. May be used in conjunction with TOGAF.

Architect

One whose responsibility is the design of an architecture and the creation of an architectural description.

Architectural Artefact

A specific document, report, analysis, model, or other tangible that contributes to an architectural description.

Architectural Description

A collection of products (artefacts) to document an architecture.

Architectural Framework

A skeletal structure that defines suggested architectural artefacts, describes how those artefacts are related to each other, and provides generic definitions for what those artefacts might look like.

Architectural Methodology

A generic term that can describe any structured approach to solving some or all of the problems related to architecture.

Architectural Patterns

Expresses commonly occurring structure of components within an application. Again, these are sometimes called Architectural Styles. At a more detailed level, an Architectural Pattern may leverage several design Patterns and Analysis Patterns. There are two broad types of Architectural Patterns, Business Application Focused and Abstract Technology Focused e.g. Layers, Pipes & Filters.

Architectural Process

A defined series of actions directed to the goal of producing either an architecture or an architectural description.

Architectural Taxonomy

A methodology for organizing and categorizing architectural artefacts.

Architecture

The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

Architecture Description

Work product used to express an architecture.

Architecture Framework

Conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders.

Architecture Layer

Logical partitioning of the architecture.

Architecture View

Work product expressing the architecture of a system from the perspective of specific system concerns.

Architecture Viewpoint

Work product establishing the conventions for the construction, interpretation and use of architecture views to frame specific system concerns

Archive World

Totality of all information in the information world whose validity or up-to-dateness has expired and which can, thus, no longer be changed.

Note 1: Information losing its validity or up-to-dateness is transferred to the archive world.

Note 2: No statement is made regarding the time at which information is transferred from the model world or state world to the archive world.

Arduino

An open-source physical computing platform which serves to create interactive objects, that's based on a simple microcontroller board. In the IoT, Arduino is used by beginners and experts alike to develop interactive objects for a variety of purposes.

AI Artificial Intelligence

Artificial Intelligence is the development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages and to take actions that maximize its chance of success at some goal.

Asset

Major application, general support system, high impact program, physical plant, mission critical system, personnel, equipment or a logically related group of systems.

Assurance

Grounds for justified confidence that a claim has been or will be achieved.

AJAX Asynchronous JavaScript + XML

AJAX allows web pages to be updated asynchronously by exchanging small amounts of data with the server behind the scenes. This means that it is possible to update parts of a web page, without reloading the whole page.

Attack Surface

Elements and interactions of a system that are vulnerable to attack.

Attack Vector

Path or means (e.g. viruses, e-mail attachment, web pages, etc.) by which an attacker can gain access to an entity.

Attacker

Person deliberately exploiting vulnerabilities in technical and non-technical security controls in order to steal or compromise information systems and networks, or to compromise availability to legitimate users of information system and network resources.

Attestation

Issue of a statement, based on a decision that fulfilment of specified requirements has been demonstrated.

Attribute

Characteristic or property of an entity that can be used to describe its state, appearance or other aspects.

Audit

Independent review and examination of records and activities to assess the adequacy of system controls, to ensure compliance with established policies and operational procedures and to recommend necessary changes in controls, policies or procedures.

Augmented Behaviour

Technologies and techniques that improve compliance with prescribed action.

Aul Augmented Intelligence

Analytical tools that improve the ability to describe, predict, and exploit relationships among phenomena.

Augmented Reality

By incorporating virtual information in real-time into the physical information available on any item or object, a mixed effect is created capable of increasing our perception of that item or object.

Authenticated Identity

Identity information for an entity created to record the result of identity authentication.

Authentication

Provision of assurance that a claimed characteristic of an entity is correct.

Authorisation

Granting of rights, which includes the granting of access based on access rights.

Note: authorization results in privileges.

Autonomy

Ability of an intelligent system to independently compose and select among different courses of action to accomplish goals based on its knowledge and understanding of the world, itself, and the situation.

Availability

Property of being accessible and usable upon demand by an authorized entity.

Batch Size 1

Unique, one-off products for everyone. Industrie 4.0 is creating the basis for implementing the highest levels of customization – all the way down to batch size 1 – within industrial manufacturing. This means high-quality, single-piece production at the price of current, uniform, mass-produced goods. The networking of all systems involved in production, and their extreme flexibility, will make the fulfilment of individual customer requirements a matter of routine in the smart factory. While the desire for customized products is already a megatrend today, it will develop to become one of the decisive competitive factors in the near future. This trend not only offers new market opportunities for products, but also gives traditional industrial nations the chance to return previously outsourced production capacity to locations in high-wage countries.

Beacon

Single pixels embedded in a website or the body of an email and effectively invisible to users. When a webpage or an email with such a pixel is opened, it sends a request to the pixel owner's server for an image – allowing the owner to track the event.

Behavioural Analytics

A type of business analytics that examines consumer or user behaviour data to understand how and why individuals behave the way they do, with the goal of making more accurate predictions about future behaviours.

Behavioural Data

Data relating to activities such as web browsing, TV viewing or the usage of telecoms services, which might be used to ascertain a customer's needs or preferences..

Big Data

High-volume, high-velocity and high-variety information requiring innovative forms of information processing for enhanced understanding and decision making.

Blockchain

Blockchain technology is being internationally recognized as one of the most disruptive innovations of the 21st century. Technology which, in spite of being complicated to understand, represents a transformation in the way we currently conduct transactions. The first application of this technology was with the appearance of the famous "Bitcoin" cryptocurrency, but it has both financial and non-financial applications. Blockchain technology allows virtually everything of value that can be expressed digitally to be recorded: birth certificates, title deeds, votes, financial accounts, product data, formulas, contracts, etc. All this is performed more quickly, securely and transparently than with traditional alternatives".

BLE Bluetooth Low Energy

BLE (Bluetooth 4.0) is a lower-energy-consumption version of the Bluetooth wireless communications standard, which runs constantly, announcing a device's presence to local sensors and optimizing battery life for the device in question. In the IoT, BLE allows for precise location and feature tracking without reduced battery life.

Browser

A software program used to locate and show information on the internet.

Business Architecture

Describes the processes the business uses to meet its goals.

BI Business intelligence

A set of methodologies and tools that analyse, report, manage, and deliver information that is relevant to the business, and that includes dashboards and query/reporting tools similar to those found in analytics. One key difference between analytics and BI is that analytics uses statistical and mathematical data analysis that predicts future outcomes for situations. In contrast, BI analyses historical data to provide insights and trends information.

Choreography between Services

Self-organizing interaction between service users in the context of higher-level specifications.

Cloud Computing

The cloud is a shared platform of computing resources such as servers, storage and applications, which can be used as required and which can be accessed from any fixed or mobile device with Internet access. Industry environments and processes can take advantage of this infrastructure.

Cloud Robotics

Shared intelligence. Nowadays smartphones, tablets and computers utilize data and processing power from the cloud as a matter of course. In the context of Industrie 4.0, robots too will be able to access decentralized data in networks or in the cloud, thereby significantly boosting their performance and flexibility. The robot itself will only require a small chip to control functionality, motion and mobility. For the task at hand, specific services will be retrieved from the cloud or individual robots networked on an ad hoc basis to form temporary production teams. In this way, specialists will become universalists that can be used for a wide range of different manufacturing processes. Cloud robotics enables the implementation of a broad spectrum of different industry-specific applications via “Robotics as a Service®”. Another effect of the cloud: robots learn from one another. If one robot encounters an obstacle, for example, it posts this information to the connected systems, which can use it to respond intelligently to the obstacle.

CNN Convolutional Neural Network

In machine learning, a convolutional neural network (CNN, or ConvNet) is a class of deep, feed-forward artificial neural networks that has successfully been applied to analysing visual imagery.

Collaborative Robotics

Industrial robots are no longer in closed work environments and isolated from each other, but will operate next to workers, share their space and collaborate with them. A new generation of manageable lightweight robots will form the so-called “smart factory”.

CSV Comma Separated Values

A comma separated value file which allows data to be saved in a table structured format. CSVs look like a spreadsheet but with a .csv extension. Traditionally they take the form of a text file containing information separated by commas, hence the name.

Command

Request to carry out an action.

Communication Ability

The manner in which data are exchanged with a participant or the participant can exchange these data and whether the participant exchanges data.

Note: various protocols.

Communication Behaviour

Specific manifestation of communications. Examples: synchronous/asynchronous, acknowledged/not acknowledged/with reply, deterministic/non-deterministic, stateful/stateless, unicast/multicast/broadcast.

Communication Channel

Connection between a transmitter/sender and recipient/receiver which allows the exchange of information.

Component

Modular, deployable and replaceable part of a system that encapsulates implementation and exposes a set of interfaces.

Component Based

The 4IR systems selected or developed should establish a culture of reuse, in which the portability and modularity is the primary design goal.

Component Manager

Organizer of self-management and of access to the resources of the I4.0 component, for example, I4.0 component, item, technical functionality, virtual representation.

Note: In many documents, component manager is referred to as resource manager, but the term component manager should be used in future.

Composability

Capability of a component to interact with other components in recombinant fashion to satisfy requirements based on the expectation of the behaviours of the interacting parties.

Composition

Result of assembling a collection of elements for a particular purpose.

Comprehensiveness

As the IT architecture seeks to provide the widest possible solution or support to the business at large, the architecture should also be such that it covers the current and future environment of the organization, tending towards completeness.

CAD Computer Aided Design

Computer-aided design software is used by architects, engineers, drafters, artists, and others to create precision drawings or technical illustrations. CAD software can be used to create two-dimensional (2-D) drawings or three-dimensional (3-D) models.

CAM Computer Aided Manufacture

Computer-aided manufacturing is the use of software to control machine tools and related ones in the manufacturing of work pieces.

CNC Computer Numerical Controller

Computer numerical control is the automation of machine tools by means of computers executing pre-programmed sequences of machine control commands. This is in contrast to machines that are manually controlled by hand wheels or levers, or mechanically automated by cams alone.

Computer Vision

Computer vision enables a computer to be able to detect the characteristics of an image, through the recognition of patterns and training and, with the support of certain computer programmes, extract information from the image for decision-making.

Conceptual Level Architecture

Represents the overall structure of the application and its interfaces to systems that are internal and external to an organization.

Confidentiality

Property that information is not made available or disclosed to unauthorized individuals, entity or processes.

Connectivity Endpoint

Interface that provides connectivity.

Consistency

Change is rapidly required, and the approach selected should facilitate this by enabling engineering harmony between the existing environment and the new or enhanced infrastructure systems, applications, business and manufacturing processes.

CoAP **Constrained Application protocol**

A software protocol that is used in small electronics devices. It serves the interactive communication between those devices.

Context

Additional information from a relationship or an environment that can be taken into consideration.

Control Domain

Collection of functions that are performed by industrial control systems.

Note: The core of these functions comprises fine-grained closed-loops, reading data from IoT sensors, applying rules and logic, and exercising control over the physical system through IoT actuators.

Cookie

Small text files placed by a website's server on a user's device when they visit it. Cookies vary in the functions they perform – some are intended to help improve users' experience of the site, while others may share contextual and behavioural information with the cookie's owner.

Core Model

Reference model of basic concepts and contexts which concern a general aspect of systems.

Credential

Evidence or testimonials that support a claim of identity or assertion of an attribute and usually are intended to be used more than once.

Criticality

Measure of the degree to which an organization depends on an entity for the success of a mission or of a business function.

Cryptography

Discipline that embodies principles, means and mechanisms for the transformation of data in order to hide its information content, prevent its undetected modification and/or prevent its unauthorized use.

CRM Customer Relationship Management

A CRM system helps you keep your customer's contact details up to date, track every interaction they have with your business, and manage their accounts. It's designed to help you, improve your customer relationships, and in turn, customer lifetime value.

CPPS Cyber Physical Production System

CPS which is used in production.

CPS Cyber Physical System

System which links real (physical) objects and processes with information-processing (virtual) objects and processes via open, in some cases global, and constantly interconnected information networks.

Note: A CPS optionally uses services available locally or remotely, has human-machine interfaces, and offers the possibility of dynamic adaptation of the system at runtime.

CPU Central Processing Unit

A central processing unit is the electronic circuitry within a computer that carries out the instructions of a computer program by performing the basic arithmetic, logical, control and input/output (I/O) operations specified by the instructions.

Cyber Security

In a digitized environment, the protection of any important company information, or cyber security, becomes increasingly important. Cyber security means all the technologies and services that protect the company from any attack or loss of data.

Dashboard

Displays information about the IoT ecosystem to users and enables them to control their IoT ecosystem.

Data

For example, numbers, text, images, and sounds, in a form that is suitable for storage in or processing by a computer.

Data Aggregation

The process of compiling information from different data sources in preparation for data processing or statistical analysis.

Data Aggregator

A company that compiles data to sell to others.

Data Analyst

A person responsible for working with end business users to define the types of analytics reports needed in the business, and then capturing, modelling, preparing, and cleaning the required data for the purpose of developing analytics reports on this data that business users can act on.

Data Analytics

The science of examining data with software-based queries and algorithms with the goal of drawing conclusions about that information for business decision making.

Data Architecture

The data management architecture refers to the data models created within the 4IR enterprise in order to facilitate the creation of a common view of the data resources within the organization, and common methods for assessing and integrating data including augmented intelligence. This standardization allows all users better access to business data, integrated business views dependent upon integrated data, and data-facilitated (analytics) real-time response to market opportunities.

Data Governance

A set of data management policies and practices defined to ensure that data availability, usability, quality, integrity, and security are maintained.

Data Integrity

Property that data has not been altered or destroyed in an unauthorized manner.

Data Mining

An analytical process where large datasets are explored or “mined” in search of meaningful patterns, relationships or insights. The process can include machine learning, statistics or artificial intelligence.

Data in Motion

Data being transferred from one location to another.

Data Repository

A central data storage area.

Data at Rest

Stored data that is neither being processed nor transferred.

Data in Use

Data being processed.

Data Ownership

Who owns the data? The data belong to the originator. A principle that is regrettably contested in the cloud. The open exchange of data and information, however, is a vital ingredient of Industrie 4.0. To put this on a secure footing, it is necessary to create platforms that comply with high ethical standards conforming to German data protection

laws. Particularly with a view to the horizontal networking of various companies within a production process, the question of data sovereignty is of central importance. With cloud solutions meeting the highest data security standards, KUKA offers unique platforms on the basis of which customers can exchange their own data with others or enrich them with new intelligence and additional information.

Data Scientist

An expert in computer science, mathematics, statistics, and/or data visualization who develops complex algorithms and data models for the purpose of solving highly complex problems.

Data Value Chain

The series of interrelated actions by which consumer data is generated, collected and processed commercially to create value – and the relationships between the parties involved.

Data Visualization

The use of visual representation of data (including infographics, charts, maps) with goals that include sense making, effective communication of information, and improved pattern detection.

Database

A large, organized collection of data that allows easy access, management, updating and analysis of information.

Databus

Data-centric information sharing technology that implements a virtual, global data space, where applications exchange data.

Note: key characteristics of a databus are

- Applications directly interface with the operational data.
 - Databus implementation interprets and selectively filters the data, and
 - Databus implementation imposes rules and manages quality of service (QoS) parameters, such as rate, reliability and security of data flow.
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Decentralized Intelligence

Intelligence evolves in the swarm. Decentralized intelligence will play an important role in Industrie 4.0: all parties can communicate with one another – work piece with machine, machine with machine or with higher-level processes. No central “brain” will control and monitor the things, but rather autonomous production units will carry out this function for both heterogeneous and homogeneous teams. Decentrality makes for greater flexibility and quicker decisions. Intelligence evolves in the swarm or through joint networking with the cloud.

DL Deep Learning

Deep learning (also known as deep structured learning or hierarchical learning) is part of a broader family of machine learning methods based on learning data representations, as opposed to task-specific algorithms. Learning can be supervised, semi-supervised or unsupervised.

DLaaS **Deep Learning as a Service**

Deep learning methods and algorithms provided as a cloud service and consumed through a service level agreement.

Demographic Change

Society is getting ever older. In principle, the term “demographic change” is a neutral reference to any alteration in the age structure of a society. At present, however, it is being widely used as a synonym for increasing over aging in the industrial nations. A trend that is diametrically opposed to the rapid growth of the global population. By the year 2020, more than half of the German population will already be over 50 years of age. An ever smaller number of people in employment will have to generate the entire productive output for the social systems. This challenge can only be met if the remaining workers become considerably more productive than all generations before them. At the same time, opportunities must be created for older, experienced employees to participate in the world of work for longer.

DoS **Denial of Service**

Prevention of authorized access to resources or the delaying of time-critical operations.

DoDAF **Department of Defence Architecture Framework**

The standard for defence architectures especially in the United States.

Deployment View

Structural mapping of applications to resources.

Note: Practical example is the distribution of the contents of an administration shell across different IT systems.

Descriptive Analytics

An initial stage of data processing that involves creating a summary of historical data with the goal of producing useful information or, answering the question, “What happened?”

Design Patterns

Works with commonly occurring structure within components. These are fine-grained concepts compared to Architectural Patterns and RAs and are useful during detailed design.

DaaS Desktop as a Service

Desktop-as-a-service is a form of virtual desktop infrastructure (VDI) in which the VDI is outsourced and handled by a third party. Also called hosted desktop services, desktop-as-a-service is frequently delivered as a cloud service along with the apps needed for use on the virtual desktop.

Deterministic Interaction

Interaction in which the state transition which can be observed is unambiguously determined due to the information received.

Digital Enterprise

One of the biggest aspects of the adoption of 4IR, is that it reached outside the factory walls. A connected supply and value chain means greater visibility of locations and activities across the whole enterprise, rather than just the internal position.

Digital Passport

A term which embraces the concept of a product carrying an electronic ledger of all sources, processes and interventions which it has undergone. The concept is based on the use of distributed ledger technologies to increase trust in the information which it contains.

Digital Representation

Data element representing a set of properties of a physical entity.

Digital Shadow

Virtual image of real things. The digital shadow is a digital image of a real object. These data contain both the current status and the desired status of the object, the possible ways and processes for achieving the desired status, and the history of what the object has already gone through. It is only the combination of a digital shadow and a physical object that results in a smart thing. Every physical product can be manufactured more efficiently and with higher quality in the digitized production facility if a digital shadow has been created for it and it bears its own specific DNA.

DSP Digital Signal Processing

A digital signal processor is a specialized microprocessor, with its architecture optimized for the operational needs of digital signal processing. The goal of DSPs is usually to measure, filter or compress continuous real-world analogue signals.

Digital Supply Chain

Transcending all boundaries. The digital supply chain merges the major business processes of all parties involved – from the suppliers to the manufacturer and the end customer. The potential of a digitized value creation chain lies primarily in the acceleration of the production and logistics processes, the reduction of effort for data acquisition and the optimization of data security and consistency. With integrated networking, the digital value creation chain is able to overcome current media discontinuity. One example from the field of procurement: where a steel-processing company previously had to activate a complicated process via different media for purchasing and replenishment, in the future purchasing will be automated on the basis of predefined parameters. Companies today are already making use of digital value creation chains to optimize individual production islands and processes within their organization. In the factory of tomorrow, the digital supply chain will also encompass global procedures across company boundaries, controlling them largely autonomously. As the most flexible machine ever conceived by man, the robot plays a central role in the digital supply chain. In its function as the core component of intelligent automation solutions, it increases the entrepreneurial freedom of action, secures competitive advantages, speeds up production processes and assures quality in the long term.

Digital Twin

A digital twin is a digital replica of a physical machine or system. It uses data from sensors installed on physical objects to represent their near real-time status, working condition or position. The delivery of this data can be through simple dashboards or through the use of a 3D geometrical model of the machine or system allowing contextualised location of data sources. If a snapshot of the real-time status is taken, and then fed into a predictive simulation model, this model is no longer a twin, but instead can be considered to be a Digital Master, especially if the physical world is then adjusted based on this master.

Digitization

Potential of the digital transformation. Converting real products and analogue sequences into digital data and processes is referred to as digitization. In Industrie 4.0, people, machines and industrial processes are networked on the basis of cyber physical systems incorporating state-of-the-art information and communications technology. In this context, the intelligent exchange and interpretation of data determine the entire life cycle of a product: from the idea to development, manufacturing, use and maintenance through to recycling. Production and logistics processes will be globally networked beyond the factory gates in the future for the purpose of optimizing the flow of materials, detecting non-conforming parameters at an early stage and enabling a highly flexible reaction to changing customer requirements and market conditions.

Distributed File System

A mechanism that stores files on servers and allows clients, with permission, to store and process files as if they were stored on their own computer.

Domain

Context of application.

Ecosystem

Loose community of various autonomous players connected in a network with a common goal of creating products and/or services based on a (standardized) communication and system infrastructure.

Note 1: Players can be participants of the value-added system as well as educational or research institutions, political units, standardization organisations or associations.

Note 2: Within an ecosystem, players can be engaged at the same time both in cooperation and in competition.

Note 3: An ecosystem is characterized by a common further development (co-evolution) of the players and the ecosystem.

Edge Gateway

Gateway that provides an entry point into enterprise or service provider core networks.

Element

Entity that is indivisible at a given level of abstraction and has a clearly defined boundary.

Embedded Compliance

It is better to build compliance into your day-to-day processes instead of having a separate compliance process which often results in unnecessary overhead. Automation is critical. For example, Instead of holding reviews to ensure that development teams follow

corporate data conventions, a time consuming and expensive endeavour, why not instead run a static code analysis tool against the database schemas on a regular basis to ensure that the data naming conventions are followed?

Embedded Computer

A term for computing that is dedicated to a single purpose, as opposed to general-purpose computing. Embedded computer systems are special-purpose and contain only the software and hardware needed to achieve those ends. In the IoT, many systems are developed for specific purposes and made to work in concert with other systems.

Encryption

Reversible operation by a cryptographic algorithm converting data into cipher text so as to hide the information content of the data.

Endpoint

Component that has computational capabilities and network connectivity.

EA Enterprise Architecture

An architecture in which the system in question is the whole enterprise, especially the business processes, technologies, and information systems of the enterprise.

ERP **Enterprise Resource Planning**

Enterprise resource planning is business process management software that allows an organization to use a system of integrated applications to manage the business and automate many back office functions related to technology, services and human resources.

Entity

Item that has recognizably distinct existence.

Note: e.g. a person, an organization, a device, a subsystem or a group of such items.

Event

Sudden change that can be observed.

Note: An event can trigger a state transition in a state model.

Extensibility

Every architectural component should be enterprise wide to the fullest possible extent.

XML **Extensible Mark-up Language**

In computing, Extensible Mark-up Language is a mark-up language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

FEA **Federal Enterprise Architecture**

The 2002 Federal Enterprise Architecture (FEA) guidance on categorizing and grouping IT investments (issued by the US Federal Office of Management and Budget). Can be viewed as either an implemented enterprise architecture or a proscriptive methodology for creating an enterprise architecture.

FEAF **Federal Enterprise Architecture Framework**

A federal enterprise architecture framework issued by the US Federal CIO council.

FTP **File Transfer Protocol**

The File Transfer Protocol is a standard network protocol used for the transfer of computer files between a client and server on a computer network. FTP is built on a client-server model architecture and uses separate control and data connections between the client and the server.

FTPS **File Transfer Protocol Secured**

A secure encrypted version of the FTP protocol.

Firmware

Low-level software for booting and operating an intelligent device.

Note: firmware generally resides in persistent memory on the device.

Flexibility

Flexibility in all dimensions. Flexibility is the ability to react quickly to changing influences. In the smart factory, utmost flexibility results primarily from the combination of IT technologies, such as the Cloud and Big Data, with intelligent, generic production units incorporating robots and autonomously controlled mobile units. The factory of the future will not have any predefined routes or rigid processes. Mobile units will equip robots “on the fly” with other tools, enabling them quickly to carry out new tasks or process other work pieces. The smart factory is therefore able to manufacture different products or product versions without any significant retooling times. It thus completely redefines the concept of flexibility in production.

Flexible Architectures

Architectures that are service-oriented, component-based, or object-oriented and implement common architectural and design patterns lend themselves to greater levels of consistency, reuse, and adaptability.

Fog

An architecture approach that uses a collaborative multitude of end-user clients or near-user edge devices to carry out a substantial amount of temporary storage, communication, control, configuration, measurement and management.

Functional Component

Functional building block needed to engage in an activity realized by an implementation.

Functional Domain

Top-level functional decomposition of an industrial internet of things (IIoT) system that provides a predominantly distinct functionality in the overall system.

Functional Framework

Set of abstract re-useable functional components that can be extended/customized and applied to several applications in a specific domain.

Functional Viewpoint

Functional components in an industrial internet of things (IIoT) system, their structure and interrelation, the interfaces and interactions between them, and the relation and interactions of the system with external elements in the environment, to support the usages and activities of the overall system.

Functionality (Technical)

Services of the I4.0 component that create the added value of an object.

Note 1: The (technical) functionality is part of the administration shell.

Note 2: The (technical) functionality can be located in the functional layer or in the integration layer of the RAMI 4.0.

Gartner Methodology

Can be best described as an enterprise architectural practice.

Gateway

Forwarding component, enabling various networks to be connected.

GPRS General Packet Radio Service

General Packet Radio Services is a packet-based wireless communication service that promises data rates from 56 up to 114 Kbps and continuous connection to the Internet for mobile phone and computer users.

GIS Geographic Information System

A geographic information system lets us visualize, question, analyse, and interpret data to understand relationships, patterns, and trends.

GPS Global Positioning System

Global Positioning System is a network of orbiting satellites that send precise details of their position in space back to earth. The signals are obtained by GPS receivers, such as navigation devices and are used to calculate the exact position, speed and time at the vehicles location.

GSM Global System for Mobile Communications

Global System for Mobile communication is a digital mobile telephony system that is widely used in Europe and other parts of the world. GSM uses a variation of time division multiple access and is the most widely used of the three digital wireless telephony technologies.

GPU Graphics Processing Unit

A graphics processing unit is a specialised electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display device. GPU technologies are often used to deploy Artificial Intelligence and Deep Learning algorithms.

Hadoop

Administered by the Apache Software Foundation, Hadoop is a batch processing software framework that enables the distributed processing of large data sets across clusters of computers.

HANA

A software/hardware in-memory computing platform from SAP designed to process high-volume transactions and real-time analytics.

Haptic Technology

A form of touch feedback that imbues human/machine interactions with tactile responses. Sensors may detect pressure and direct feedback like vibrations and noises. In the IoT, haptic technology serves to facilitate human interaction with machines.

HMD Head Mounted Device

A Head mounted device can be a pair of goggles or a full helmet. In front of each eye is a tiny monitor. Because there are two monitors, images appear as three-dimensional. In addition, most HMDs include a head tracker so that the system can respond to head movements.

HPC High Performance Computing

High Performance Computing most generally refers to the practice of aggregating computing power in a way that delivers much higher performance than one could get out of a typical desktop computer or workstation in order to solve large problems in science, engineering, or business.

HPCaaS High Performance Computing as a Service

Cloud Computing attempts to provide HPC-as-a-Service exactly like other forms of services currently available in the Cloud such as Software-as-a-Service, Platform-as-a-Service, and Infrastructure-as-a-Service. HPC users may benefit from the Cloud in different angles such as scalability, resources being on-demand, fast, and inexpensive.

Historic Analytics

The study of past historical data to research potential trends, to analyse the effects of certain decisions or events, or to evaluate performance.

Homonym

Same designation for different concepts.

Note: The context can be used to exclude homonyms.

Horizontal Integration

Integration within a functional/organizational hierarchical level across system boundaries.

Horizontal Integration

Dynamic company networks. Exact coordination is not only indispensable for internal process optimization within a company, but also between all companies involved in the value creation chain. This horizontal integration – networking between different enterprises – is the starting point for the flexible design of their shared value creation processes. In the era of Industrie 4.0, companies will form dynamic networks in the future, linking order-specific and product-specific capacities in virtual production communities. Current data from the production-relevant processes will enable fast and precise reactions – for instance to planning changes or unexpected events occurring inside or outside an individual company. Production and logistics processes adapt to the real situation in real time, boosting the long-term flexibility and efficiency of the companies acting within an integrated concept.

Host

Hosts are computers that provide (host) certain services or resources within a network, which other participants within the network can then access and use.

Human Machine Interaction

Collaboration between – users and technology, such as computers, machines or CPS.

Note 1: Implemented by human- and task-oriented technical systems at the interface between users and technology.

Note 2: Includes the analysis, design and evaluation of such systems.

Note 3: Collaboration synonymous to interaction.

HMI Human Machine Interface

The user interface in a manufacturing or process control system. It provides a graphics-based visualization of an industrial control and monitoring system. Previously called an “MMI” (man machine interface), an HMI typically resides in an office-based Windows computer that communicates with a specialized computer in the plant such as a programmable automation controller (PAC), programmable logic controller (PLC) or distributed control system (DCS).

Human-Robot Collaboration

The best of two worlds. Until now, industrial robots always worked separately from humans in specially safeguarded protected spaces. Robotics have broken down this barrier with a new generation of collaborative industrial robots. With human-robot collaboration (HRC), combine the skills of humans with their superior creativity and cognitive abilities and the robot with its greater repeatability, strength and precision. In this way, the robot becomes the third arm of the human operator. This new form of collaboration opens up previously inconceivable possibilities for the smart factory of the future.

HTTP Hypertext Transfer Protocol

The Hypertext Transfer Protocol is an application protocol for distributed, collaborative, and hypermedia information systems. HTTP is the foundation of data communication for the World Wide Web. Hypertext is structured text that uses logical links (hyperlinks) between nodes containing text.

HTTPS Hypertext Transfer Protocol Secured

A secure encrypted version of the HTTP protocol.

I4.0 Component

Globally uniquely identifiable participant with communication capability consisting of administration shell and asset within an I4.0 system which there offers services with defined QoS (quality of service) characteristics.

Note 1: For its services and data, the I4.0 component offers protection commensurate with the task.

Note 2: An I4.0 component can represent a production system, a single machine or station, or even an assembly within a machine.

I4.0 Platform

Implementation of a (standardized) communication and system infrastructure with the necessary management and production services and defined QoS (quality of service) characteristics as a basis for the efficient construction and integration of I4.0 systems in an application domain.

Note 1: To ensure interoperability, an I4.0 platform must be based on a reference architecture.

Note 2: An I4.0 platform must define a relation to the I4.0 system.

I4.0 System

System, consisting of I4.0 components and components of a lower CP classification, which serves a specific purpose, has defined properties, and supports standardized services and states.

Note 1: A system may be present as a component in a further I4.0 system.

Note 2: An I4.0 system must define a relation to the I4.0 platform.

Identification

Process of recognizing an entity in a particular identity domain as distinct from other entity.

ID Identifier

Identity information that unambiguously distinguishes one entity from another one in a given identity domain.

Identity

Set of properties related to an entity.

Note: In a particular domain of applicability, an identity can become a distinguishing identity or an identifier to allow entities to be distinguished or uniquely recognized within that domain.

Identity Authentication

Formalized process of identity verification that, if successful, results in an authenticated identity for an entity.

Identity Domain

Environment where an entity can use a set of attributes for identification and other purposes.

Identity Information

Set of values of attributes optionally with any associated metadata in an identity.

Note: in an information and communication technology system an identity is present as identity information.

Identity Verification

Process to determine that presented identity information associated with a particular entity is applicable for the entity to be recognized in a particular identity domain at some point in time.

Individual Concept

Term, which represents or designates an individual item or instance.

Individualized Production

Meeting every customer requirement. Individualized, or customized, production refers to the concept of an intelligent, highly automated production system that allows high variance and dynamism in the product range with production costs at the level of mass production. The goal is to resolve the conflict between the customer's desire for individualization and the process efficiency of production in an industrial setting. A batch size of 1 is the highest level of customized production. Besides proprietary solutions in the automotive sector, Industrie 4.0 with its

universally networked production environments represents the world's most advanced approach for implementing customized production.

Industrial Internet

Internet of things, machines, computers and people, enabling intelligent industrial operations using advanced data analytics for transformational business outcomes.

IIC Industrial Internet Consortium

The Industrial Internet Consortium will enable and accelerate adoption of the Industrial Internet which is essential to growth and competitiveness in key industry sectors, including: manufacturing, transportation, energy, healthcare, buildings, utility infrastructure, defence, and emergency response.

IIoT Industrial Internet of Things

System that connects and integrates industrial control systems with enterprise systems, business processes and analytics.

Note 1: industrial control systems contain sensors and actuators.

Note 2: typically, these are large and complicated system.

IIRA Industrial Internet Reference Architecture

A standards-based architectural template and methodology enables Industrial Internet of Things (IIoT) system architects to design their own systems based on a common framework and concepts.

IIS Industrial Internet Systems

Internet Information Services is an extensible web server created by Microsoft for use with the Windows NT family. IIS supports HTTP, HTTP/2, HTTPS, FTP, FTPS, SMTP and NNTP. It has been an integral part of the Windows NT family since Windows NT 4.0, though it may be absent from some editions.

I4.0 Industrie 4.0

Industrie 4.0 originates from a project in the high-tech strategy of the German government, which promotes the computerization of manufacturing and is the original definition of 4IR, I4.0 etc.

I4.0 Industry 4.0

Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing.

Inferred Data

Informed suppositions generated on the basis of the available evidence. By analysing sets of data, firms may be able to infer broad characteristics about individuals to varying degrees of accuracy.

Infomediary

An intermediary whose role in the data value chain is the obtaining, exchange or processing of data, typically on behalf of other market participants.

Information

Computer data that has been organized and presented in a systematic fashion to clarify the underlying meaning.

IAM Information Access Management

The security discipline that enables the right individuals to access the right resources at the right times for the right reasons.

Information Domain

Collection of functions for gathering data from various domains, most significantly from the control domain and transforming, persisting, and modelling or analysing those data to acquire high-level intelligence about the overall system.

IT Information Technology

Information technology is the application of computers to store, study, retrieve, transmit, and manipulate data, or information, often in the context of a business or other enterprise. IT is considered a subset of information and communications technology (ICT).

Information World/Digital World/ Cyber World

Ideas, thought constructs, algorithms, models, and the totality of representations of physical objects and people in a virtual environment.

Note 1: The frame of reference of the totality in question must be defined.

Note 2: The elements of the information world can be related to each other via semantics.

IaaS Infrastructure as a Service

Refers to an on-demand business model for IT capacities. Instead of owning IT infrastructure or server space you rent it and pay for it on a per-use basis. Those capacities are usually owned, maintained and provided by a cloud service. These are specific services that are essential for any IoT implementation to work properly. Such services provide support for essential features of the IoT.

Infrastructure Service

Service that is essential for any IoT implementation to work properly.

Note: Infrastructure services provide support for essential features of the IoT.

IGES Initial Graphics Exchange Specification

The Initial Graphics Exchange Specification is a vendor-neutral file format that allows the digital exchange of information among computer-aided design (CAD) systems.

Initial Graphics Exchange Specification

A vendor-neutral, standardized file format that is used to transfer information between CAD (computer-aided design) programs. The standard was developed to create a uniform method for exchanging graphical data between the programs.

Insight (Hindsight and Foresight)

The 3 sights are derived from data. Insight can be considered to be knowledge derived from real-time performance. Hindsight is knowledge derived from historical performance and foresight is knowledge derived from predicted performance.

Instance

Specific entity which has the properties and manifestations of a type.

Integrity

Property of accuracy and completeness.

Interaction

Related actions of two or more entities.

Note: An interaction can be, for example, deterministic, non-deterministic, asynchronous, synchronous, stateful or stateless.

Interface

Defined connection point of a functional unit which can be connected to other functional units.

Note 1: “Defined” means that the requirements and the assured properties of this connection point are described.

Note 2: The connection between the interfaces of function units is also called an interface.

Note 3: In an information system, the defined exchange of information takes place at this point.

Note 4: An interface places certain requirements on the connection that is to be made.

Note 5: An interface demands certain features.

Intermediary

A company that carries out functions in the value chain between two parties (for example between a publisher and an advertiser).

loA Internet of Automation

Basis for efficient production. Both the Internet of Automation (loA) and the Internet of Robot Things (loRT) make use of defined open communications and data standards to network interoperable production processes even across company boundaries. In the near future, it will be possible for all the cyber-physical elements involved in the automated manufacturing process to be networked in the loA and to communicate with the loRT.

loRT Internet of Robot Things

The device (robot) is intelligent in the sense that it has embedded monitoring (and sensing) capabilities and at the same time can get sensor data from other sources which are fused for the 'acting' purpose of the device. A second 'intelligent' part is that the device can leverage local and distributed "intelligence".

loT Internet of Things

Defines the connectivity of objects through a communication protocol. Everything from a watch to the condition of a shipping container in the middle of the ocean can be tracked, monitored and configured via the internet. It delivers real-time knowledge of an environment the user wants to control. The development of sensors and communicating technologies such as 5G networks provide low-cost opportunities.

IP/IPv6 Internet Protocol (v6) Address

An identifier that enables communications over the internet. IP addresses are either static (assigned by an ISP) or dynamic (reset dynamically by the ISP on a regular basis).

ISP Internet service provider

An Internet service provider is an organization that provides services accessing and using the Internet. Internet service providers may be organized in various forms, such as commercial, community-owned, non-profit, or otherwise privately owned.

IOP Interoperability

Ability of different components, systems, technologies, or organizations to actively work together for a specific purpose.

Note: Interoperation is collaboration put into practice.

Item

Unit which exists objectively, is demarcated and identifiable.

Note 1: An item can be virtual or physical in nature.

Note 2: An item can be a device, subsystem, software program, plan, living organism, organization or the like.

Note 3: An item has a life cycle.

JSON JavaScript Object Notation

JSON is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language.

KPI **Key Performance Indicator**

A Key Performance Indicator is a measurable value that demonstrates how effectively a company is achieving key business objectives. Organizations use KPIs to evaluate their success at reaching targets.

Knowledge

All the information, facts, truths, and principles learned throughout time and application of previously gained experience or known theory.

Layer

Suggested structure for describing architectural aspects of I4.0 components and I4.0 systems.

Note 1: vertical axis of RAMI4.0.

Note 2: comparable/similar to IIRA viewpoints.

Legacy system

An established computer system, application, or technology that continues to be used because of the value it provides to the enterprise.

Local Storage

Special type of electronic data storage that contains information about one or only a few entities in the vicinity of a device.

Location Technology

All location technologies like Global Positioning Systems (GPS) work to establish and communicate the location of a device to sensors around it. In the IoT, this capability serves to position a device or user within a system.

Logistics

Now. Everything. Always. Customized products and same-day delivery – customers have a growing expectation that everything will be available in all places, at all times. This ubiquity places the utmost demands on the logistics and process chains and is increasingly embracing the stationary retail sector and the structure of merchandise flows. The boundaries between individual delivery channels are successively vanishing and modern distribution centres are often being set up directly in metropolitan areas thanks to the reduced space requirements. Changes that can only be addressed through highly transparent, digitized networking of production and logistics.

LTE Long Term Evolution

In telecommunication, Long-Term Evolution is a standard for high-speed wireless communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements.

Lucidity

Where IT organizations are expected to respond to constant change, the Enterprise Architecture should play a bridging role, establishing clear targets for change and making them understandable to the organization in clear business language. It is also becoming clear with 4IR that organization must distinguish between change through growth (continuity), which is 'more of the same'; versus real change (disruptive), which introduces different design perspectives, roles and actions.

ML Machine Learning

Machine learning is a field in which machines can 'learn' without explicit programming. Evolved from the study of pattern recognition and computational learning theory in artificial intelligence, machine learning explores the study and construction of algorithms that can learn from and make predictions on data – such algorithms overcome following strictly static program instructions by making data driven predictions or decisions, through building a model from sample inputs.

M2M Machine-to-Machine

M2M relates specifically to the interconnection of devices, usually wirelessly – such as devices that track a car's location or monitor its engine's performance.

Machine-to-Machine Communication

Machine to machine communication is one of the breakthrough benefits of having smart connected machines. Smart machines can make decisions based

on machine learning, artificial intelligence and historical data. A single machine's decisions may influence other machines in the process chain through the communication of its own decision.

Map/reduce

A big data batch processing framework that breaks up a data analysis problem into pieces that are then mapped and distributed across multiple computers on the same network or cluster, or across a grid of disparate and possibly geographically separated systems. The data analytics performed on this data are then collected and combined into a distilled or “reduced” report.

Manifest

Externally accessible defined set of meta-information, which provides information about the functional and non-functional properties of the I4.0 component.

Note: The manifest can be regarded as similar to the manifest in computer science.

MaaS Manufacturing as a Service

Access rather than possession. Digitization has substantially changed the approach to physical possession. It is increasingly being replaced by temporary access to goods or services. The best example: music streaming. What has already become an everyday situation in many consumer segments will also revolutionize the industrial environment over the next few years. As the name suggests, “Manufacturing as a Service” will see manufacturing processes purchased as services: the machine itself does not change ownership – payment is made for the performance of the machine only. What applies to complete production systems will,

in the future, also apply to individual elements within a manufacturing facility, for example to robots. On the basis of a “pay-per-use” model, it will not be the physical object itself that is purchased in conjunction with “Robotics as a Service[®]”, but rather its performance, such as weld spots in vehicle body production, for instance. The smart factory of the future integrates these services seamlessly into its production processes and thus has the capability of reacting to varying capacity requirements and goods flows exceedingly flexibly and efficiently while conserving resources at the same time.

MES Manufacturing Execution System

Manufacturing execution systems are computerized systems used in manufacturing, to track and document the transformation of raw materials to finished goods. MES provides information that helps manufacturing decision makers understand how current conditions on the plant floor can be optimized to improve production output. MES works in real time to enable the control of multiple elements of the production process (e.g. inputs, personnel, machines and support services).

Mass Customisation

One of the goals of the digital enterprise is to be able to create one-off, consumer-defined, products in a cost effective way using flexible manufacturing processes and configurations.

MDM Master Data Management

In business, master data management is the comprehensive method used to consistently define and manage the critical data of an organization to provide a

single point of reference. The data that is mastered may include reference data- the set of permissible values, and the analytical data that supports decision making.

Megatrends

What makes the world go round? Customization, digitization, responsible use of natural resources and demographic changes are the megatrends that will need to be mastered in the coming decades. With a forecast world population of 8 billion by the year 2025 and 10 billion by 2060, ever more customer requirements of increasing diversity will need to be satisfied. At the same time, demographic changes will be confronting industrialized and emerging countries with economic and social challenges over the long term. Humanity is thus facing a fundamental paradigm shift which will undoubtedly have far-reaching consequences for our worldwide economic systems. That is why Industrie 4.0 does not describe a purely technical innovation scenario but rather a way in which intelligent technology can help to overcome the global challenges of the 21st century. As a thought leader and trailblazer for Industrie 4.0.

Message Broker

A message broker is a middleware program that translates a message from the messaging protocol of the sender into the messaging protocol of the receiver. This way a message broker makes it easier for two applications to communicate.

MQTT **Message Queueing Telemetry Transport**

A lightweight messaging protocol for small sensors and mobile devices. Useful for connections with remote locations where a small code footprint is required.

Metadata

Data created by combining personal, anonymous or pseudonymous data for multiple individuals as a group.

MoDAF **Ministry of Defence Architecture Framework**

The Ministry of Defence Architecture Framework - the UK standard for defence architectures.

Mobile Application

Software application or program that is installed specifically on mobile devices (for example, a smartphone or tablet).

Model

Coherent, sufficiently detailed abstraction of aspects within a field of application.

Model World

Totality of all meta documents, plans and descriptions in the information world.

Monitoring & Stream Analytics

Data in real time. Monitoring and stream analytics compare and analyse data that are available to the smart factory from diverse sources – devices, sensors, infrastructure, etc. In real time they make comparisons with data records from the past and recognize anomalies, which can be categorized as faults with the aid of machine learning. On this basis intelligent systems can initiate immediate countermeasures and generate forecasts and recommended actions for the future.

NAF NATO Architecture Framework

The NATO Architecture Framework - a standard adopted for NATO allies.

NFC Near Field Communication

Is a set of wireless technologies which allows for simple and contactless exchange of data within very close distance (a few inches).

Network

A mechanism for communicating an electronic signal.

Network Layer

Responsible for transmitting the data collected by the physical layer to different devices.

NNTP Network News Transfer Protocol

Network News Transfer Protocol is an application protocol used for transporting Usenet news articles (net news) between news servers and for reading and posting articles by end user client applications.

NN Neural Network

Artificial Neural Networks are models inspired by the real-life biology of the brain. These are used to estimate mathematical functions and facilitate different kinds of learning algorithms. Deep Learning is a similar term, and is generally seen as a modern buzzword, rebranding the Neural Network paradigm for the modern day.

Noise

The fluctuations in the output signal resulting from the sensor or the external environment.

Non-deterministic Interaction

Interaction in which the state transition that can be observed is not unambiguously determined due to the information received.

Note: This is the case if a system behaves spontaneously in an interaction or can show several alternative behaviours, the choice of which is not determined by the information received.

NFR Non-Functional Requirement

Requirement that does not belong to the actual system function Examples: availability, performance, usability, compatibility, maintainability, security ...

Non-Personal Data

Data that does not contain personally identifiable characteristics and cannot alone be used to identify individuals.

NoSQL

“Non-relational SQL” or “Not only SQL” is much like SQL but does not use relational tables with rows and columns. It is used to manage and stream processing of data. NoSQL includes a number of different databases and models that run horizontally, meaning across servers. This might make it more cost-effective than vertical scaling (as used in SQL).

OPC

OLE for Process Control

OPC is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries. It is platform independent and ensures the seamless flow of information among devices from multiple vendors. The OPC Foundation is responsible for the development and maintenance of this standard. OPC is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries. It is platform independent and ensures the seamless flow of information among devices from multiple vendors. The OPC Foundation is responsible for the development and maintenance of this standard.

OT

Operational Technology

Hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise.

Orchestration of Services

Flexible connection of individual services for a defined purpose.

Note: This can be done during the planning phase and/or at runtime.

OT/IT Convergence

The process or aspiration of bringing together Information Technologies and Operation Technologies (which provide operational control of assets in a network in real time). Higher efficiency and reliability may be attained with such a smart grid platform combining the physical infrastructure and human interface.

OEE Overall Equipment Effectiveness

OEE is the gold standard for improving manufacturing productivity. Understand, measure, and improve OEE, Availability, Performance, and Quality.

Party

Entity, human or logical (e.g. an administrator, a legal entity, an agent), that has some autonomy, interest and responsibility in the execution of an activity .

Note: a party may assume more than one role, and a role may be fulfilled by several parties (i.e. by any one of them).

Passively Supplied Data

Data that is observed by businesses and collected in the background as consumers undertake activities – for instance information stored by cookies as users browse online.

Personal Data

Data that can be used to identify specific individuals, either on its own or together with other data.

Physical Layer

The hardware that makes an IoT device, including sensors and networking gear.

Physical Level Architecture

Defines the physical view by identifying the technology (hardware and software) components.

Physical World

The totality of all actually existing items and individuals.
Note 1: The real world corresponds to the physical world.
Note 2: Software loaded or in memory is part of the physical world.
Note 3: The frame of reference of the totality in question must be defined.

PaaS Platform as a Service

Platform as a service is a complete development and deployment environment in the cloud, with resources that enable you to deliver everything from simple cloud-based apps to sophisticated, cloud-enabled enterprise applications.

Plug and Work

Setting up, modification or termination of interoperation between two or more involved parties with minimal effort.

Note 1: The interoperability of those involved is assumed.

Note 2: The minimum effort can vary depending on the state of the art.

Note 3: Plug & play and plug & produce are synonyms or similar terms.

PoE Power over Ethernet

Power over Ethernet describes any of several standard or ad-hoc systems which pass electric power along with data on twisted pair Ethernet cabling. This allows a single cable to provide both data connection and electric power to devices such as wireless access points, IP cameras, and VoIP phones.

PoWifi Power over Wi-fi

PoWiFi works by forcing routers to send out a constant 1W signal, rather than the intermittent kind used currently, which is then captured and turned into DC power by harvesters.

Pragmatic Governance Body

Effective governance bodies focus on enabling development teams in a cost-effective and timely manner. They typically have a small core staff with a majority of members being representatives from the governed organizations.

Predictive Analytics

The practice of extracting information from existing data sets in order to determine patterns and predict future outcomes and trends. Using predictive analytics, we can predict future events like when a machine might

fail. It does not however change a machine's operating conditions to extend remaining useful life. That would be the domain of prescriptive analytics.

Predictive Maintenance

Predictive maintenance allows machines to prevent machine downtime. Machines and systems continuously analyse their status themselves and potential problems are reported in real-time. Scheduled maintenance ensures that the machine remains operational.

Prescriptive Analytics

Automatically synthesizes big data, multiple disciplines of mathematical sciences and computational sciences, and business rules to make predictions and suggest decision options to take advantage of the predictions.

Privacy

Right of individuals to control or influence what information related to them may be collected and stored and by whom and to whom that information may be disclosed.

Private Cloud

Provides services with cloud characteristics but only within a single organization, for example a company.

Privilege

Right granted to an individual, a program or a process.

Process

Entirety of procedures in a system by means of which the material, energy or information is transformed, transported or stored.

Process Model

Model of a process as a system of coupled part-processes.

PLM Product Life-Cycle Management

Product lifecycle management is an information management system that can integrate data, processes, business systems and, ultimately, people in an extended enterprise. PLM software allows you to manage this information throughout the entire lifecycle of a product efficiently and cost-effectively from ideation, design and manufacture through service and disposal.

PLC Programmable Logic Controller

Electronic device designed for control of the logical sequence of events.

Property

Feature of an entity.

Pseudonymous Data

Information collected and used at the level of individuals, which may contain personal information such as age range and gender, but where personal identifiers are not present (for instance, because they have been stripped out and replaced with artificial identifiers or pseudonyms).

Public Cloud

Services are public and made available for everyone.

PKI Public Key Infrastructure

Structure of hardware, software, people, processes and policies that uses digital signature technology to provide relying parties with a verifiable association between the public components of an asymmetric key pair with a specific subject.

RFID Radio Frequency Identification

The use of electromagnetic or inductive coupling in the radio frequency portion of the spectrum to communicate to or from a tag through a variety of modulation and encoding schemes uniquely to read the identity of an RFQ Tag. A method to identify objects (including humans) through electromagnetic waves without actual physical contact. This way, data can be gathered more easily. An object or creature is equipped with a transponder which transmits data to an electronic reader. Other than, for example, barcodes, the information can be read without a line of sight and in some cases operating distance can be over a kilometre.

Range

The band of input signals within which a sensor can perform accurately. Input signals beyond the range lead to inaccurate output signals and potential damage to sensors.

Raspberry Pi

A credit-card sized personal computer that plugs into a TV and a keyboard. The device helps to democratise programming, since it's inexpensive, available to the masses, and can do many of the things that desktop PCs can do.

Real-time Analytics

Dynamic analysis and reporting, based on data entered into a system less than one minute before the actual time of use.

RTLS Real-Time Localisation System

Real-time locating systems are used to automatically identify and track the location of objects or people in real time, usually within a building or other contained area.

RAMI4.0 Reference Architecture Model for Industry 4.0

RAMI 4.0 combines all elements and IT components in a layer and life cycle model. RAMI 4.0 breaks down complex processes into easy-to-grasp packages, including data privacy and IT security.

RA Reference Architectures

Reference Architecture is an end-to-end architecture which has already been created for a particular domain of interest. It typically includes different Architectural Patterns (also know as architectural styles), applied in different areas of its structure. There are two broad types of Reference Architectures: Industry Specific RA & Technical RA.

Reference Model

Model which is used generally and is recognized as appropriate (with the character of a recommendation) in order to derive specific models.

Reliability

Ability of a system or component to perform its required functions under stated conditions for a specified period of time.

Repeatability

A sensor's performance in consistently reporting the same response when subjected to the same input under constant environmental conditions.

REST Representational State Transfer

REST is an architecture for web standards, especially for the HTTP protocol. It is supposed to simplify the design of network applications compared with, for example, SOAP. An architecture for representing entities exposed by a Web Service in order to interact with them (Create, Read, Write, Delete). Has become very popular as a more efficient alternative to traditional SOAP Web Services.

Requirement

Specification of required criteria.

Note: The system can fulfil the required criteria step by step, if necessary.

Re-Shoring

Available is the new cheap. Whereas in the past purchase decisions were often primarily made on the basis of the lowest price, in the future it will be the product that is available most quickly and with a high level of customization that will be at the top of consumers' shopping lists. This necessitates new manufacturing and marketing methods and structures that will only become possible as a result of networked production in smart factories. Short distances will be an important factor in achieving fast availability. Due to the high degree of automation, production steps that are currently outsourced to low-wage countries can be repatriated to high-wage countries in a process known as "reshoring". Irrespective of wage structures, intelligent automation allows cost-efficient and high-quality production in the vicinity of the consumers.

Resilience

Ability of a system or component to maintain an acceptable level of service in the face of disruption.

Resolution

The smallest incremental change in the input signal that the sensor requires to sense and report a change in the output signal.

Resource Efficiency Sustainable production

The ability of humanity to handle the future will be determined by a responsible and sustainable approach to natural resources. In a just world, it may be assumed that

ever more people will want to be supplied with ever better products. Flexible, intelligent and networked production as envisaged in Industrie 4.0 offers the opportunity of using raw materials more efficiently and more sustainably along the entire value creation chain and recycling them to a great extent for the sake of the planet.

Robotic Governance

Creating a responsible future world for generation “R”. Robotic governance is a concept which, among other things, considers the ethical/moral, socio-cultural, socio-political and socio-economic effects of robotics on society and provides a framework for solving problems resulting from these changes. The governance principles include accountability, responsibility, transparency of structures and fairness. In this way, robotic governance helps to create a sustainable and responsible future world for the upcoming generation “R”.

Robotic Natives

Robots as natural companions. Future generations, “robotic natives”, will see robots as the state of the art, as a lifestyle, or quite simply as normal. Just as commonplace as smartphones and the Internet, for example, are for the digital natives of today. They will have overcome the old human versus machine antagonism. The robot-oriented generation will shape a society that not only works differently, but also thinks differently. It will see the capabilities of robots as universal, networkable services that can be requested via the Internet and flexibly adapted to the requirements and desires of the individual at the click of a mouse. While nowadays robots are primarily known as work assistants in industrial processes, in the future they will be found in all areas of our daily lives

as driverless cars, robot-furniture, carebots and a wide range of home and personal assistants. By 2050, a robot in every household will be part of everyday life.

Robustness

Ability of a system or component to continue functioning correctly in the presence of invalid inputs or stressful environmental conditions.

Role

Set of usage capacity.

Note 1: a role is an abstraction for an entity which performs the set of activities.

Note 2: roles are fulfilled or assumed by parties.

Scalability

The IT architecture should look for solutions that can grow, morph or even mutate as the business requires it, depending on the changes that occur in the business environment.

Scenario-Driven Development

The whole cannot be defined without understanding the parts, and the parts cannot be defined in detail without understanding the whole. By taking a scenario-driven, also called a usage-driven approach, you can understand how people will actually use your system, thereby enabling you to build something that meets their actual needs. A common mistake made by traditional data approaches is that they take data-driven approaches (understandable, given their biases) which gets them in trouble because data is too narrowly focused to drive things and it doesn't reflect the needs of your overall governance effort.

Security

Property of being protected from unintended or unauthorized access, change or destruction ensuring availability, integrity and confidentiality.

Selectivity

The sensor's ability to selectively sense and report a signal. An example of selectivity is an oxygen sensor's ability to sense only the O₂ component despite the presence of other gases.

Sensor

A device that generates an electronic signal from a physical condition or event.

Sentiment Tracking

Tools and services that enable companies to gain insights on how their brands and products are being discussed online. By analysing the extent to which they are mentioned in social media content, including whether trends are positive or negative and why, firms may adjust their marketing activity.

Service

Distinct part of the functionality that is provided by an entity through interfaces.

Service Consumer

Entity or organization that consumes the service of a provider.

Note: An entity or an organization can be a consumer and a provider (both at the same time).

Service Orientation

Paradigm which enables the straightforward exchange, addition or removal of loosely coupled services.

Service Provider

Entity or organization that provides a service.

Note: An entity or an organization can be a consumer and a provider (both at the same time).

Service Robotics

Robots enter daily life. Even today, useful robotic assistants are making everyday life easier. Small, specialized service robots, for example, have long since established themselves in our private sphere. They are deployed as assistants in the home – vacuuming, mowing the lawn or cleaning windows. As yet, their capabilities are mostly limited to a single task. However, they do demonstrate one thing: collaboration between humans and robots works in everyday life. Thanks to the progressive development of service robotics, robots will shape daily life in the future in various ways. Whether it be as a nursing robot in clinical settings, as helpers for the elderly at home or as assistants in many other areas which today sound futuristic. For the robotic natives of tomorrow, service robots will be as self-evident as smartphones are for people of the present.

Servitisation

This consists of new ways of conceiving the relationships between users and providers of assets, based more on the provision of service than the delivery of physical goods as such. These relationships require partnership and cooperation between the parties involved, and sharing the risks and benefits of using the assets provided. It also involves new ways of conceiving the payment and collection models that regulate financial relationships between users and providers of assets (for example, via pay per use, depending on the capacity that a provider makes available to a user or on performance-based contracts).

SMS Short Message Service

Short Message Service is a text messaging service component of most telephone, World Wide Web, and mobile device systems. It uses standardized communication protocols to enable mobile devices to exchange short text messages.

SMTP Simple Mail Transfer Protocol

Simple Mail Transfer Protocol is a protocol for sending e-mail messages between servers. Most e-mail systems that send mail over the Internet use SMTP to send messages from one server to another; the messages can then be retrieved with an e-mail client.

Smart Data

Intelligent data exchange. If Big Data is the oil of the future, then Smart Data is the fuel that drives the production of the future. Currently, data are just data. To turn them into information, they must be interpreted.

This is the step from perception (recognizing) to cognition (understanding). Books, for example, are at first merely collections of letters. They only become knowledge when they are processed and interpreted in the brain. In the context of intelligent automation, the central focus is on the topics of data communication, process modelling, machine learning, autonomous self-configuration and process optimization.

Smart Device

A smart device is a device, generally connected to other devices or networks via different protocols such as Bluetooth, NFC, Wi-Fi, 3G, etc., that can operate to some extent interactively and autonomously.

Smart Factory

Factory whose degree of integration has reached a level which makes self-organizing functions possible in production and in all business processes relating to production.

Note: The virtual representation of the factory makes intelligent decisions possible. The aim is to increase efficiency, effectiveness, flexibility and/or adaptability.

Smart Platforms

Intelligent and flexible. New, intelligent platforms will be created for the implementation of Industrie 4.0. They will support collaborative industrial processes and use their services and applications to network people, things and systems. The result will ensure greater flexibility and a continuous flow of information: smart platforms will document the entire business process, work safely and reliably at all levels, and support mobile end devices and collaborative production, service, analysis and forecast processes along the entire digital supply chain.

Smart Product

Produced or manufactured (intermediate) product which in a smart factory delivers the (outward) communication capability to network and to interact intelligently with other production participants.

Note 1: The product is a produced or manufactured article or semi-finished product.

Note 2: A digital image is part of the product intelligence and can be localized on the product itself but also spatially separate from it.

Note 3: Unique identification and product-related information makes it possible for the product to be linked to the smart factory.

Smart Production

Dialogue between smart factory and smart product.

Social Machines

Interconnected. Intelligent. Flexible. Machines in production which are intelligently interconnected, communicate with one another and can instantaneously react to deviations and changes in an independent, situation-based manner are called social machines. They are part of the Industrie 4.0 vision. The underlying idea is that machines share their knowledge like in social networks – information about themselves as well as experiences and “lessons learned” from their processes. At the same time, social machines coordinate the information received and learn from the network too. Similarly to Facebook users, they independently obtain information from the Internet and connected social machine networks. Through swarm experience, they are aware of the best parameters for machining a particular material, for example, and they exchange them with “befriended” machines.

SaaS **Software as a Service**

Software is delivered to the user and updated via the internet. Typically enabled by a cloud service that hosts the software. Often there is no software installed on the user's device but it is accessed via a web browser. Although this is not a requirement of SaaS, for example, Adobe and Microsoft both deliver applications that are installed on the user's device through a SaaS model.

SDK **Software Development Kit**

A software development kit is typically a set of software development tools that allows the creation of applications for a certain software package, software framework, hardware platform, computer system, video game console, operating system, or similar development platform.

Specification Level Architecture

Defines the logical view of the Functional (i.e. Component) and Operational Models.

Standard

Commonly accepted prohibitions or prescriptions for action.

Standardization

General requirements for reliable interaction. In the course of any technical evolution, different solutions, formats and approaches usually compete with one another – developed and propagated by various fractions, committees or companies. Only standardization, with its exact and binding definition of framework parameters and the possible interfaces, makes it possible to create

appropriate expansions, counterparts and communication bridges to a new technology. Of particular importance in this context with regard to the implementation of Industrie 4.0 are the new definitions of safety in the area of human-machine collaboration and the standardization of interoperability in the area of data exchange.

Standards

The basis of all constructive cooperation. Standards are the elementary basis for breaking down barriers in the globalized world of Industrie 4.0. In this way, it is creating new standards to ensure interoperability in the smart factory of tomorrow.

State

Manifestation of the characteristics of an object at a certain point in time.

Note 1: An object can only have one state at any point in time.

Note 2: Statements about a state can be made without any specific reference to a time.

State World

Totality of information currently collected in the information world.

Structured Data

Any data that has been organized into structured fields, such as a database or spreadsheet, so that it can be easily processed or analysed. Examples include dates, words and numbers.

SQL Structured Query Language

SQL is used to communicate with a database. According to ANSI (American National Standards Institute), it is the standard language for relational database management systems. SQL statements are used to perform tasks such as update data on a database, or retrieve data from a database. Some common relational database management systems that use SQL are: Oracle, Sybase, Microsoft SQL Server, Access, Ingres, etc.

SCADA Supervisory Control and Data Acquisition

SCADA is a computer system which gathers real-time data to monitor and control systems or processes.

Supportability

This involves the capability of the solution not only to support the full extent of the business; but also to be supported by its provider on a local or global basis.

Synonym

Different names or designations for the same concept. Note: Depending on the context, one of the synonyms may be used more commonly.

System

A multitude of components that are all related to each other.

SOR System of Record Data

Data that is typically found in fixed record lengths, with at least one field in the data record serving as a data key or access field. System of records data makes up company transaction files, such as orders that are entered, parts that are shipped, bills that are sent, and records of customer names and addresses.

Technology Architecture

Technology architecture refers to the standards and policies created to define the computing technology infrastructure for the 4IR enterprise. It establishes technology standards to limit technology choice, to reduce the number of platforms supported, and to define a set of computing resources that organizations manage. This standardization is expected to significantly reduce the number of vendor packages and infrastructure services that perform similar functions.

Term

Conceptual unit formed by abstraction from a set of items by determining the common properties of these items.

Note: A term can be part of a terminology.

TOGAF The Open Group Architecture Framework

A widely used framework process including an architectural Development Method and standards for describing various types of architecture.

Time to Market

Meeting customer requirements more quickly. The time to market denotes the length of time from development of a product to its availability on the market. In the factory of the future, this time, which is often decisive for the sales success of a product, will be significantly shortened. Positive effect: changing requirements and trends in increasingly volatile markets can be met with corresponding products much more quickly than previously.

Timeliness

Temporal correctness that has yet to be specified in detail. Note: Response must be given to events at precisely defined times or events must be triggered at defined times, e. g. not before, not after, or within a specified time interval.

Traceability

Keeping track. Traceability here refers to the ability to fully trace all raw materials, producers, upstream suppliers, individual parts or assemblies as well as the complete product and its consumers in the digital value creation chain. It is possible at all times to determine when, where and by whom the goods were produced, processed, stored, transported, used or disposed of. Irrespective of whether an individual part or a finished product is concerned, a distinction is made between two directions of traceability: from the manufacturer to the consumer and from the consumer to the manufacturer.

TCP/IP **Transmission Control Protocol/ Internet Protocol**

Transmission Control Protocol/Internet Protocol, the communications suite used to transmit data on the internet.

Trustworthiness

Degree of confidence one has that the system performs as expected with characteristics including safety, security, privacy, reliability and resilience in the face of environmental disruptions, human errors, system faults and attacks.

Type

Descriptive entity that is characterized by a quantity of common properties and their type.

Understanding

Knowledge that has applied meaning and context and given a reason or cause and effect.

UMTS **Universal Mobile Telecommunications Service**

UMTS is a third-generation (3G) broadband, packet-based transmission of text, digitized voice, video, and multimedia at data rates up to 2 megabits per second (Mbps).

Unstructured Data

Information that either does not have a pre-defined data model or is not organized in a pre-defined manner. It is thus not stored in a database in structured fields. Examples include text, images, audio, video.

Validation

Examination/testing of described/defined requirements for a predefined application or use.

Note: A product fulfils the requirements of the customer, i.e. examination according to the customer requirement specifications was successful.

Validation

Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.

Value (Data)

Value is the most important 'V'. It is all well and good having access to big data but unless we can turn it into value it is useless.

Value Added Chain

Sequence of value-creation processes (linear or hierarchical, formally this means directed acyclically).

Note: Corporate boundaries are not necessarily relevant to a value-creation chain or value chain.

Value Added Process

Process from which goods valuable to customers arise.

Note 1: The goods in question may be not only physical in nature (such as raw materials, products) but even intangible (such as knowledge, data and services).

Note 2: Value assessment and pricing are not considered here.

Note 3: Value-creation processes are value activities according to Porter.

Value Added System

Network or system consisting of value-creation chains or value chains which can include not only cross-connections but also dependencies between them.

Valued Corporate Assets

Guidance (such as database design conventions, modelling style guidelines, data naming conventions, and report design guidelines), metadata definitions, and reusable assets such as frameworks and components, will be adopted if they are perceived to add value to developers. You want to make it as easy as possible for developers to comply to, and more importantly take advantage of, your corporate IT infrastructure. When data standards are sensible, easy to understand, and easy to access then there is a significantly greater chance that people will actually follow the standards in practice. When you force people to conform to standards, when it make it onerous for them to do so, then you reduce the chance that they will actually do so.

Variety (Data)

Refers to the different types of data we can now use. 80% of the world's data is now unstructured, and therefore can't easily be put into tables. With big data technology we can now harness differed types of data (structured and unstructured) including messages, photos, sensor data, video or voice recordings and bring them together with more traditional, structured data.

Velocity (Data)

Refers to the speed at which new data is generated and the speed at which data moves around. Big data technology allows us now to analyse the data while it is being generated, without ever putting it into databases.

Veracity (Data)

Refers to the messiness or trustworthiness of the data. With many forms of big data, quality and accuracy are less controllable. Volume often makes up for the lack of quality or accuracy.

Verification

Examination/testing of the requirements described/ defined in the specifications.

Note: A product fulfils the specifications, i.e. examination according to the functional requirement specifications was successful.

Vertical Integration

Integration within a system which crosses functional/ organizational hierarchy levels.

VPN **Virtual Private Network**

A virtual private network is a technology that allows you to create a secure connection over a less-secure network between your computer and the internet.

Virtual Reality

Virtual reality allows the user to fully enter a simulated environment that seems real but is actually computer generated.

Virtual Representation

Digital models of the I4.0 component throughout the entire life cycle.

Note 1: The virtual representation is part of the administration shell.

Note 2: The virtual representation can be located in the information layer or in the integration layer of the RAMI4.0.

Note 3: The manifest is part of the virtual representation.

Volume (Data)

Refers to the vast amounts of data generated every second. This increasingly makes data sets too large to store and analyse using traditional database technology. With big data technology we can now store and use these data sets with the help of distributed systems, where parts of the data is stored in different locations and brought together by software.

Vulnerability

Weakness of an asset or security controls that can be exploited by one or more threats.

Wi-Fi **Wireless Fidelity**

Wifi is a technology for wireless local area networking with devices based on the IEEE 802.11 standards. Wi-Fi is a trademark of the Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing.

Wisdom

Is the ability to increase effectiveness. Wisdom adds value, which requires judgment. The ethical and aesthetic values that this implies are inherent to the actor and are unique and personal.

ZF **Zachman Framework**

A classification scheme for EA artefacts launched in the early 1980s by John Zachman - often considered the father of enterprise architecture is actually more accurately defined as a taxonomy.

ZigBee

Low-power radio protocol for small amounts of data, based on the IEEE 802.15.4 standard. It has low power consumption, a range of about a 100 metres and a bandwidth of 250 kbps. IoT staples like the Nest thermostat and Hue light bulb both use ZigBee chips.

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