Technology: sWave.NET

Abstract

sWave.NET® was launched in 2016, based on the already established sWave® wireless technology for cable-free point-to-point connections in industrial environments. Development goals included very high availability and extremely low power consumption. The target markets were industrial applications, in particular eKanban systems and special functions for AGV fleets. For these and other applications the nexy wireless system – based on the sWave.NET® wireless protocol is suitable.

Out of scope for the technology are typically open places in big areas without infrastructure for electrical installation and without power supply. Another example are Campus networks.

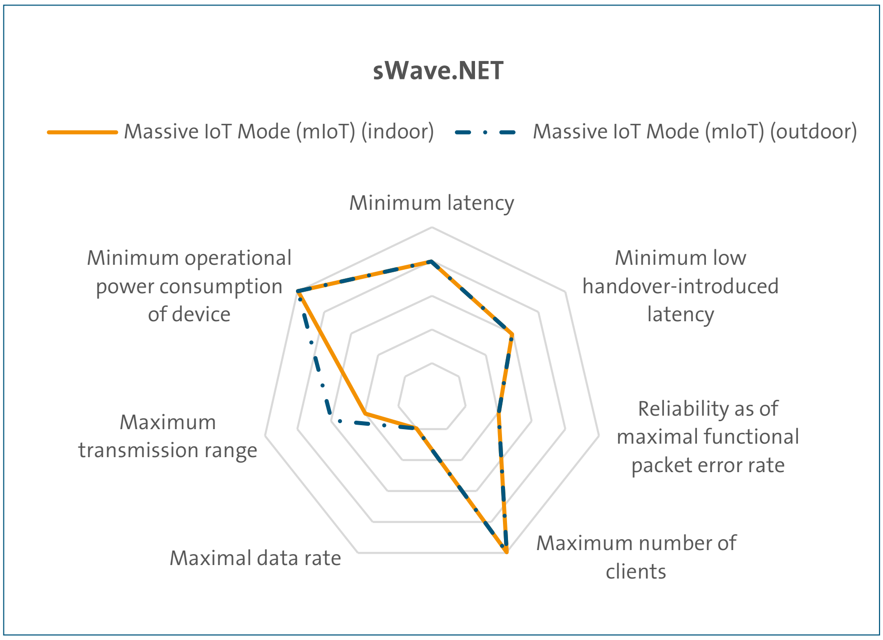
Also, the system is not suitable for very fast and synchronous real-time data. Instead, the system is made for a highly reliable data transmission with repetitions if needed to prevent data loss.

The radio technology is designed for asynchronous and small data transmission in industrial environments.

Figure 1

Source / Copyright: Büro Longjaloux, Wuppertal

Technology Briefly



Note: Scale value "5" = best performance; scale value "0" = not specified. Source: ifm electronic

The properties in this diagram have been defined by consensus within WCM-Working Group 2.

In addition to a consensual definition, the property values refer to requirements described in reference use cases. This is done to ensure a degree of comparability between wireless communication systems.

The reference use cases have been described by the WCM-Working Group 1, providing specific requirements for:

- Realtime / Ultra low latency communication (e.g. discrete manufacturing)
- Streaming/high data rate (e.g. video streaming)
- Massive Industrial Internet of Things (mIIoT) / Sensor Networks (e.g. valve status)

Property Definitions

Minimum Latency

Nominal achievable latency for the given reference use case and the associated functional packet error rate (FPER) property.

- Assuming that all clients are able to fulfill this latency requirement at the same time
- The latency is measured from reference input interface to reference output interface of the wireless communication system (e.g. Layer2/3)
- The latency and FPER of the spider diagram need to be achievable at the same time as they are linked together

Minimum Handover-Introduced latency

Minimum latency added to the nominal latency when a handover of a single device occurs for the given use case. Handover assumes operation of all devices of the usecase with the associated FPER.

Reliability as of maximal Functional Packet Error Rate, where Functional PER:

Percentage of data that is delivered later than the nominal latency for a given reference use case due to errors on the channel, late channel access, scheduling, or whatever other reason.

- Assuming that all clients are at the maximum range and at line of sight
- Assuming that all devices have to fulfill the same latency requirement (provided by the minimum latency property)
- Assuming that all clients fulfill the same FPER requirement
- FPER and latency of the spiderdiagram need to be achievable at the same time as they are linked together

Maximum number of clients

The maximum supportable number of clients for the given reference use case. This means the number of clients servable by one access point/base station/node in a meshed network/relay.

- Assuming that all devices in that scenario have the same communication requirements
- The available spectrum for the property is defined by the maximum bandwidth supported by the technology.
  It needs to be in line with the data rate property
- Per default the frequency regulation of Germany is referenced

Maximum Data Rate

The maximum/peak user data rate (payload) achievable per device for the given reference use case. Assuming that all devices in that scenario have the same communication requirements.

Minimum Operational Power Consumption of Device

Mean power consumption in Watt [W] for the given reference use case.

- This references the power consumption of a known device/node for that use case
- The time duration for the averaging is defined by the use case

Maximum Transmission Range

Maximum distance from a single transmitter to a single receiver

- Assuming maximum allowed transmission power (EIRP)
- Assuming typical receive antennas for the application
- The frequency band is also defined by the application
- Assuming line of sight communication

The “Technical Parameters” chart in the “Detailed Technology Description” section provides further information on these properties and other Key Performance Indicators (KIPs).

A brief description of the reference use cases can be found in the Appendix.

Disclaimer: This graph is based on the information provided by the authors of this chapter – a list of authors can be found at the end of the publication – available at the time of publication. It reflects an approximate performance of the communications system at a high level, based on the requirements specified in reference use cases.

This performance may of course vary depending on the degree of customization possible in defining the specific requirements for each industrial application and on the specific implementation. Thus, dialogue between the industrial user and wireless experts is encouraged to explore all possibilities.

High-level Technology Description

Topology

The system setup has the following components: Sensors and actors, Access Points, Sensor Bridge. The sensors and actors are the nodes of the wireless system. The Access Points collect the data from the nodes wirelessly and communicate with the Sensor Bridge.

The Sensor Bridge has, next to the user interface, several interfaces for the customer IT. The Rest API is one of the possible interfaces.

Interfaces

The Sensor Bridge supports the following variety of interfaces for communication:

REST API, HTTP POST, Modbus TCP, OPC UA, MQTT, SAP RFC

Time Behaviour

In many industrial applications, the response and reaction times of the (wireless) network play a crucial role. An sWave.NET® sensor communicates with an Access Point which then confirms reception of the wireless telegram after just a few milliseconds. If no response is received, the node repeats the telegram at random intervals, up to 30 times within roughly 16 seconds.

A wake-up timer can be configured for any node. Starting with wake-up intervals of 1 minute the wake-up is used for health monitoring of the node, for example the battery status of the node.

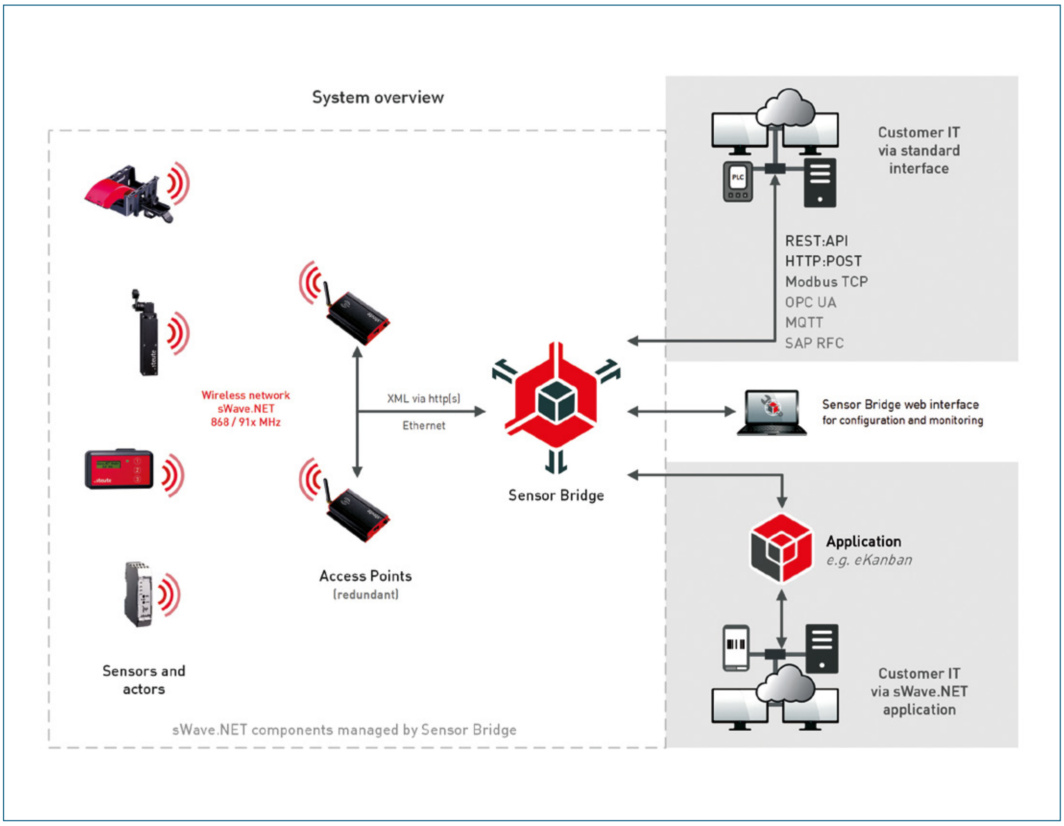


Figure 2

Source / Copyright: Büro Longjaloux, Wuppertal

Spectrum

The frequencies are in the licence free spectrum. The spectrum is in the sub-gigahertz band and is available for worldwide use (e.g. 868 MHz, 915 MHz, 916 MHz, 917 MHz).

Coexistence

In order to prevent interference with other nodes on the same frequency, the sWave.NET® network uses multiple collision avoidance strategies. In order to guarantee successful transmission, each wireless telegram sent by a node must be confirmed by the Access Point it arrives at.

In order to prevent other wireless protocols on the same frequency from being disturbed, 20 out of the 30 repeated telegrams use the LBT (listen before talk) principle. Should there be any interference from signals or other devices on the same frequency, broadcasts are sent via a special procedure prioritising up to 10 Access Points for each device using multidimensional Received Signal Strength Indicator (RSSI) ranking. Following a broadcast, the communication path with the greatest field strength is selected for communication. The RSSI ranking is also reevaluated after each new telegram. The premise for this is a wireless infrastructure design with at least twofold redundancy.

These communication principles mean that sWave.NET® wireless systems can be operated with high reliability and also be combined with other wireless technologies.

Maturity

The system has been commercially available for approx. 7 (reference date 2022). Approximately 200 of these systems are in the field. The maximum number of sensor nodes in one system is up to 10,000.

Detailed Technology Description

Technical Parameters

Parameter	**General KPIs**
Protocol	
Frequency bands	Sub-GHz ISM Band
Un-licensed frequency band	Yes
International coverage	Worldwide ISM
Real-Time capability	No
Network topology	Mesh (Automatic)
Handover (mobility) support	Yes / Automatic
Voice support	No
Localization support	No
Coexistence mitigation mode	LBT and retransmissions to multiple BS
MiMo capability	No
Typical range BS - MS	Up to 700 m
Typical range mesh	No physical limitation
Typical latency BS - MS	<10 ms for sensor trigger to end of RF transmission, then non-deterministic due to network topology and load
Typical latency with one hop in a mesh	No mesh hop topology, but fail-safe access point switch-over
Typical data rate	66.7 kbps
Maximal number of active clients	10.000 per access point
Maximal lifetime when using a battery	Up to 10 years for mechanical switch RF sensors
Expected interference immunity	Good (LBT, retries, switching between Accesspoints, narrow bandwith filter)
Likelihood of coexistence	Good (short telegramms resulting in short air time, LBT, retries, switching between Accesspoints, narrow bandwith filter)
Signal bandwidth	350 kHz
Coexistence relevant bandwidth	350 kHz
Localization accuracy	n.a.
Technology maturity level	Mature, sensors and features are added continuously. Ongoing optimization of energy consumption by keeping parts up to date.
Product availability	Available
Standardization	ETSI EN 300 220-2
Standard availability	Available
Required Infrastructure on site	Network of Access Points

Parameter	General KPIs
Massive IoT Mode (mIoT)	
Nominal latency	<10 ms for sensor trigger to end of RF transmission, then non-deterministic due to network topology and load
Handover introduced latency	<100 ms
Cycle time	6 ms (3 ms per each RF packet)
Roundtrip time	~ 10ms (3ms per RF packet + analysis time)
Maximal Functional Packet Error Rate	$<10^{-3}$
Maximum number of clients	10000
Telegram size	25 Bytes
Maximal data rate MS downlink	66.7 kbps
Maximal data rate MS uplink	66.7 kbps
Data payload per MS downlink (net)	16 Bytes
Data payload per MS uplink (net)	16 Bytes
Maximal RF power [EIRP] downlink	10 dBm
Maximal RF power [EIRP] uplink	10 dBm
Required SNR	+10 dBm - (-103 dBm) = 113 dBm
Mean power consumption in usecase	0.65 mWs
Maximum transmission range	40 m indoor 450 m outdoor
Maximum velocity of an MS	200 m/s

Technology Description

Designation	outdoor	indoor
SW868	700 m	100 m
SW915	700 m	100 m
SW922	230 m	25 m
SW917	700 m	100 m

Source: steute Technologies

Development goals: high availability, low power consumption

sWave.NET® was launched in 2016, based on the already established sWave® wireless technology for cable-free point-to-point connections in industrial environments. Development goals included very high availability and extremely low power consumption.

Typical wireless ranges

The sWave.NET® system was developed for applications using wireless sensors in industrial automation environments with short ranges. The sensors can be mounted in close proximity and in large numbers and can transmit very frequently. Due to the short range, multiple parallel subnetworks can be operated in small spaces without mutual restriction of the existing bandwidth.

There are different frequencies for different countries, e.g. SW868 for Europe. SW is the description and name for the wireless system sWave.

Application Reference

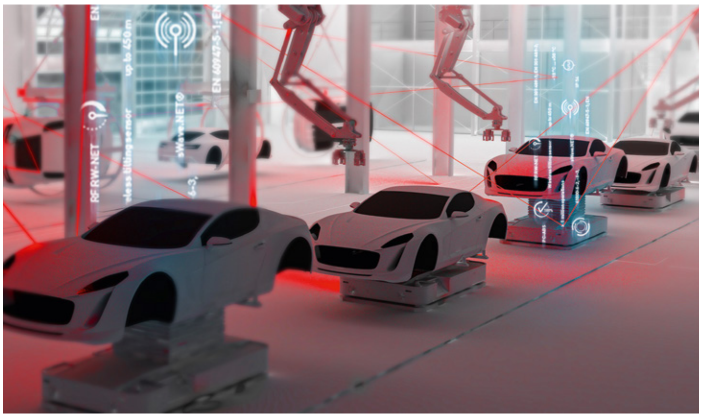


Figure 3 Source / Copyright: Büro Longjaloux, Wuppertal

Figure 4 Source / Copyright: Büro Longjaloux, Wuppertal

Application Specific Technology Description

In the following specific applications, sWave.NET-based wireless networks are used.

"Wake-up" function for AGV in deep sleep mode

AGV which are not currently in use still need power when they are standing still. It is not practicable to switch them off completely because they might be needed again at short notice. The solution: the AGV are put into a deepsleep mode and then receive a wake-up signal via the wireless nexy network. They can be put back to productive use by the management system without delay. Here, the nexy wireless network is used exclusively to control the deep-sleep mode, bringing additional flexibility.

Renowned AGV manufacturers are already using this "wake-up" function in their AGV fleets (figure 3).

eKanban systems

For the automated supply of materials to assembly points and workstations in production halls and intralogistics applications, roller conveyors within eKanban racks are fitted with smart sensors (figure 4). If a sensor registers the removal of a small load carrier (SLC) from its rack shelf, it sends the correspondent message via the nexy network, and a request for replenishment is automatically triggered in the material flow control system. This in turn triggers an order of new materials, without any need for manual activity – and provision is oriented exclusively to real requirements.

Smart rack sensors monitor individual SLC container positions – "occupied" or "free" – and inform the wireless network immediately of any changes in status. The network guarantees that status and sensor ID are passed on reliably to the material flow control system. Here there is a clear assignation between each sensor and the relevant materials. The requirement for new materials is thus detected by the system and the replenishment process automatically triggered.

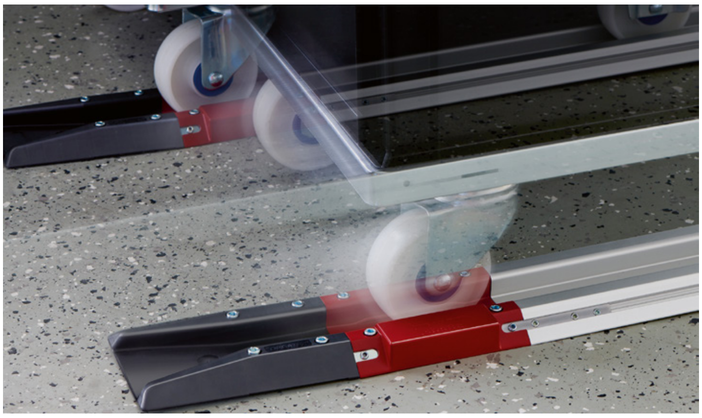


Figure 5 Source / Copyright: © Udo Kowalski

Figure 6 Source / Copyright: © Udo Kowalski

Dolly stations

In many manufacturing facilities, such as those in the automotive supply industry, materials are moved by tugger trains and dollies. Wireless sensors (figure 5) on the monorail tracks of the dolly stations integrate the dollies into the sWave.NET-based material flow control system.

Detection of pallets and palletised containers

Long-range laser sensors (figure 6) detect the presence of pallets and palletised goods in the storage areas of supermarkets and FiFo stations (First-In-First-Out). This enables seamless radio-based material tracking and control.

Container level monitoring

In addition to containers and packages themselves, the radio-based material retrieval system can also detect the fill level of containers (e.g. large load carriers and other bulk containers). These tasks are performed by short-range laser sensors with a wireless network connection.