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| **Radiocommunication Study Groups** |  |
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| **1 June 2018** |
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| Annex 34 to Working Party 5A Chairman's Report | |
| PRELIMINARY DRAFT NEW REPORT ITU-R M.[NON\_IMT.MTC\_USAGE] | |
| Technical and operational aspects of Internet of Things and Machine-to-Machine applications by systems in the Mobile Service (excluding IMT) | |

# 1 Introduction

Machine-type communications (MTC) utilise wired and wireless communication networks. The advantages of wireless technologies include reduced complexity in cabling, cable protection and plugs, increased mobility and flexibility as well as access to a “wear and tear” free transmission medium. MTC include wireless industrial automation (WIA) applications such as factory automation, process automation, audio visual interaction, remote control, mobile robotics and vehicles ranging from low latency applications to reliable and secure applications.

# 2 Scope

This report provides information on the technical and operational aspects of Machine Type Communications (MTC) including Internet of Things (IoT)/Machine to Machine (M2M) applications by systems in the Mobile Service (excluding IMT). This report also provides information on the existing and planned/future usage of Mobile Service frequency bands by IoT/M2M applications.

# 3 Related documents

## 3.1 ITU documents

[Editor’s note: check with ITU counsellor how to treat non ITU document.]

Resolution [ITU-R 66](https://www.itu.int/pub/R-RES-R.66-2015) – *Studies related to wireless systems and applications for the development of the Internet of Things*

Recommendation [ITU-R M.1450](https://www.itu.int/rec/R-REC-M.1450-5-201404-I/en) – *Characteristics of broadband radio local area networks*

Recommendation [ITU-R M.2002](https://www.itu.int/rec/R-REC-M.2002-0-201203-I/en) – *Objectives, characteristics and functional requirements of wide-area sensor and/or actuator network (WASN) systems*

Recommendation [ITU-R SM.1132](https://www.itu.int/rec/R-REC-SM.1132-2-200107-I/en) – *General principles and methods for sharing between radiocommunication services or between radio stations*

Recommendation [ITU-R SM.1896](https://www.itu.int/rec/R-REC-SM.1896-0-201111-I/en) – *Frequency ranges for harmonization of short range devices*

Working document towards a draft new Report ITU-R M.[IMT.MTC] - *The use of the terrestrial component of International Mobile Telecommunication (IMT) for Narrowband and Broadband Machine-Type Communication*

Report [ITU-R SM.2152](https://www.itu.int/pub/R-REP-SM.2152-2009) – *Definitions of Software Defined Radio (SDR) and Cognitive Radio System (CRS)*

Report [ITU-R SM.2153](https://www.itu.int/pub/R-REP-SM.2153-6-2017) – *Technical and operating parameters and spectrum requirements for short-range devices*

Report [ITU-R SM.2255](https://www.itu.int/pub/R-REP-SM.2255-2012) – *Technical characteristics, standards and frequency bands of operation for radio-frequency identification (RFID) and potential harmonization opportunities*

Report [ITU-R SM.2351](https://www.itu.int/pub/R-REP-SM.2351-2-2017) – *Smart grid utility management systems*

Working document towards a Report ITU-R SM.[LPWAN.MTC] – *Technical and operational aspects of Low Power Wide Area Networks (LPWAN) for Machine-Type Communication and the Internet of Things in frequency ranges harmonized for SRD operation*

## 3.2 Other references

[1] [ETSI TR 102 889-2 V1.1.1](http://www.etsi.org/deliver/etsi_tr/102800_102899/10288902/01.01.01_60/tr_10288902v010101p.pdf) (2011-08): Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Part 2: Technical characteristics for SRD equipment for wireless industrial applications using technologies different from Ultra-Wide Band (UWB).

[2] ECC Report 206: Compatibility studies in the band 5 725-5 875 MHz between SRD equipment for wireless industrial applications and other systems.

[3] ERC Recommendation 70-03: Relating to the use of Short Range Devices (SRD).

[4] ECC Recommendation (02)05: "Unwanted emissions".

[5] EN/IEC 61784-2:2010: "Industrial communication networks – Profiles – Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3".

[6] EN/IEC 62591: "Industrial communication networks – Wireless communication network and communication profiles –WirelessHART®".

[7] IEC 62657-2: “Industrial communication networks - Wireless communication networks – Part 2: Coexistence management”.

[8] IEEE 802.11-2016: "IEEE Standard for Information technology – Telecommunications and information exchange between systems - Local and metropolitan area networks – Specific requirements - Part 11: Wireless LAN Medium Access, Control (MAC) and Physical Layer, (PHY) Specifications".

[9] IEEE 802.15.1-2005: "IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.1: Wireless medium access control (MAC) and physical layer (PHY) specifications for wireless personal area networks (WPANs)".

[10] IEEE 802.15.4: "IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low‑Rate Wireless Personal Area Networks (WPANs)".

[11] [Draft] ETSI EN 300 440 v2.2.0: “Short Range Devices (SRD); Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Harmonised Standard for access to radio spectrum”.

[12] [Draft] ETSI EN 303 258 v1.0.6: “Wireless Industrial Applications (WIA); Equipment operating in the 5 725 MHz to 5 875 MHz frequency range with power levels ranging up to 400 mW; Harmonised Standard for access to radio spectrum”.

# 4 Abbreviations

CEPT Conference of Postal and Telecommunications Administrations

IoT Internet of Things

M2M Machine-to-Machine

MTC Machine Type Communications

WIA Wireless Industrial Automation

# 5 Overview of existing and possible future IoT/M2M applications

[Editor’s note: Need to shorten the introductory text for the information placed in the Annex]

## 5.1 Wireless industrial automation (WIA) applications

Modern automation technology applications are increasingly using wireless technologies to transfer data. But, industrial automation applications require robust technologies to be used for their critical wireless communication. The advantages of wireless technologies are savings of often complex and expensive cables, cable protection and plugs, the increased mobility and flexibility as well as the wear and tear free transmission medium.

The majority of wireless systems for industrial automation applications use the bands designated for Industrial, Scientific and Medical applications (ISM) and Short Range Devices (SRDs). The main incentive for using some of these bands is their broad harmonisation and their license-exempt status.

Details of the current use, technology and related deployments can be found in Annex 1.

## 5.2 …

# 6 Technical and operational aspects of Land-Mobile Service Based radio networks and systems to support narrowband and broadband machine-type communication

WIA applications utilise robust wireless technologies for wireless links in industrial applications. For example, a factory may use a high density of terminals and access points and multiple technologies. More and more communication technologies are being considered for these WIA applications, such as context information sensing, transmission efficiency and security technology.

# 7 Information on the spectrum usage of MTC applications

In recent years, additional varieties of new wireless applications for MTC have continued to emerge. Users of particular applications select a suitable technology based upon a number of important metrics such as reliability, simplicity, efficiency, range of transmission and cost. Massive applications of wireless intelligent terminals can facilitate the integration of real physical world and virtual network world, and achieve interconnection between resources, information, and goods.

The below table illustrates examples of frequency bands that could be used in various parts of the world for MTC.

TABLE [XX]

Examples of frequency bands that could be used for MTC

|  |  |
| --- | --- |
| Europe | 5 725–5 875 MHz is currently in use by a number of technologies for MTC |
| USA | 5 725–5 850 MHz used by applications including MTC |

# 8 Enabling and existing technologies

## 8.1 Wireless industrial automation (WIA) applications

An important technology for WIA devices is IEEE 802.11, especially devices according to the amendments IEEE 802.11n, ac and ax. Devices based on this technology offer sufficient bandwidth for various applications. For these applications, systems typically use a nominal channel bandwidth of 20 MHz, which allows to operate multiple systems in parallel and independently.

In addition devices and systems using other technology than IEEE 802.11, are in use, such as visual monitoring and video surveillance. Systems are often based on proprietary technology, but operate in accordance with the applicable regulation. According to the nature of video transmission and high bandwidth requirements these broadband systems occupy several MHz of spectrum.

# 9 Deployment scenarios and architectures

[Editor’s note: Annex 1, section XX contains the information for WIA. If no contribution other than WIA, then it proposed to make a reference to the relevant section in the Annex 1 or to be deleted.]

# 10 Summary

Machine-type communications (MTC) currently utilise existing communication network solutions. The advantages of wireless technologies include reduced cost of complex and cables, cable protection and plugs, increased mobility and flexibility as well as access to a wear and tear free transmission medium.

The Report presents information on MTC applications including wireless industrial automation (WIA). Various typical WIA applications include factory automation, process automation, audio visual interaction, remote control, mobile robotics and vehicles ranging from low latency applications (e.g. robotic arms) to reliable and secure applications (e.g. driverless autonomous transportation systems).

MTC applications are increasingly using robust wireless technologies to transfer data. This Report includes technologies already used for MTC-based on IEEE 802.11/IEEE 802.15.1 and IEEE 802.15.4. IEEE 802.11(n, ac and ax) is an important technology for WIA as devices based on 802.11 technology offer sufficient bandwidth for various applications. For WIA applications, systems typically use a nominal channel bandwidth of 20 MHz, which allows to operate multiple systems in parallel and independently.

In addition, devices and systems using technology other than IEEE 802.11 are in use for applications such as visual monitoring and video surveillance. These systems are often based on proprietary technologies operating in accordance with the applicable regulations. Due to the nature of video transmission and high bandwidth characteristics, these broadband systems can occupy [several MHz of] spectrum.

The majority of the wireless systems addressed in this Report for MTC applications utilise frequency bands that are broadly harmonised with a license-exempt status. For instance, in Europe, the 5 725‑5 875 MHz frequency band is currently in use by the number of technologies for MTC. This includes the possibility to use this frequency band for WIA applications up to 400 mW, given the implementation of appropriate spectrum access and mitigation techniques. These conditions of use are included in [draft] ETSI EN 303 258 v1.0.6.

**Annex:** 1

Annex 1

Wireless industrial automation (WIA) applications

# 1 Introduction

This Annex provides information on wireless industrial automation application. This includes information on how current radio systems for wireless industrial automation, their evolution, and/or potentially new radio interface technologies and system approaches could be appropriate, taking into account the impact of the propagation characteristics related to the possible future operation of wireless industrial applications.

Wireless industrial automation applications would require appropriate consideration of the following demands:

– very low latency and high reliability machine-centric communication;

– high user density;

– maintaining high quality (e.g. robustness and low-latency real-time behaviour) at high mobility.

Furthermore the Report ITU-R M.2370-0 describes that machine to machine communication (M2M) is a growing market in future. For that reason it is necessary to consider the technical feasibility of current and future radio interfaces for wireless industrial automation application within the framework of advanced manufacturing and Industry 4.0.

There has been recent academic and industry research and development related to suitability of wireless industrial automation applications. For that reason the [ETSI TR 102889-2](http://www.etsi.org/deliver/etsi_tr/102800_102899/10288902/01.01.01_60/tr_10288902v010101p.pdf) was developed to describe the requirements of wireless industrial automation applications. Based on the ETSI TR 102889-2, CEPT utilises the frequency range from 5 725 MHz to 5 875 MHz for wireless industrial automation application allowing an output power up to 400 mW, given the implementation of appropriate spectrum access and mitigation techniques (see [draft] ETSI EN 303 258 v1.0.6). The results of compatibility studies within the frequency range can be found in ECC Report 206.

# 2 Typical WIA Applications

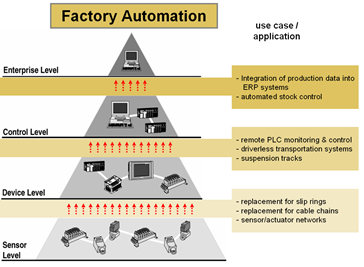
## 2.1 Overview

### 2.1.1 Factory Automation

Factory automation is used as synonym for discrete manufacturing where products are produced, assembled, tested or packed in many discrete steps (automotive, general consumer electronic, goods production). In the factories of the future, static sequential production systems will increasingly be replaced by novel, modular production systems offering high production flexibility and versatility. The concept of modular production systems encompasses a large number of increasingly mobile production assets. For these autonomous mobile assets, powerful wireless communication and localisation services are required. For factory automation, in-time deliveries of messages and high reliability (robustness) are very important to avoid interruptions in the manufacturing process which leads to production loss. Redundancy, cyber security and functional safety are also very important for factory automation. Typically, every manufacturing step involves many sensors and actuators controlled by a single controller (e.g. Programmable Logical Controller). Many of these use wired connections which are often stressed by repeated movements and/or rotations and other harsh conditions.

Figure A1-1

Automation hierarchy in a discrete manufacturing factory plant with example technologies used



Today more and more devices, especially sensor and actuator nodes with relaxed requirements, are connected using wireless technology to improve productivity and increase availability compared to wired sensors/actuators at difficult locations.

Motion control is characterized by high requirements on the communications system regarding latency, reliability, and availability.

Application examples

– Automatic guided vehicles (AGV);

– Monorail systems;

– Conveyer belts;

– Single and collaborating mobile robots;

– High-bay storage / Intra logistics;

– Portal crane;

– Communication to rotating or moving machine parts;

– Assistance systems for workers and operators:

• Video cam & display (e. g. Hololense);

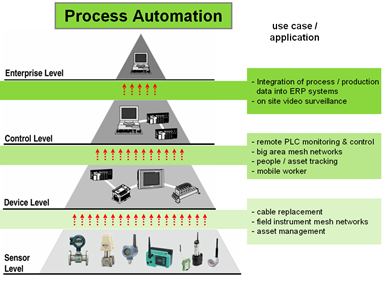
• Mobile control panels.

### 2.1.2 Process Automation

Process automation is defined as an automation application for industrial automation processes. It is typically associated with continuous operation, with specific requirements for determinism, reliability, redundancy, cyber security, and functional safety. Process Automation is typically used for continuous production processes to produce or process large quantities or batches of a certain product (like fluids, chemical, or an "endless" product like e.g. wires, cables).

Figure A1-2

Automation hierarchy in a process plant with example technologies used



Process applications also require deterministic behavior and therefore require low latencies in the range between 100 ms and a few seconds. Process automation can cover relatively large areas and so wide wireless transmissions ranges are required. The end nodes (sensors) in process automation applications potentially have to have a battery life of several years.

On the sensor level you can find mesh networks for field instruments, based on different wireless mesh protocols. The mesh structure helps to achieve a large range coverage with standard low power levels and to be robust. On higher levels of the automation hierarchy e.g. at the control or enterprise level, where the data volume rises (e.g., portable supervisory stations), so throughput, security and availability becomes more important, but real–time communication requirements decrease.

Process automation covers, for example, the following industries: oil & gas, refining, chemical, pharmaceutical, mining, pulp and paper, water and wastewater and steel.

Application examples

– Portable supervisory station (commissioning, maintenance);

– Process sensors;

– Environmental sensors;

– Access to (high-level) information of field devices not transmitted over the 4 – 20 mA current loop.

### 2.1.3 Audio-visual interaction

Audio-visual interaction is characterized by a human being interacting with the environment or people, or controlling a device, and relying on audio-visual feedback.

### 2.1.4 Remote control

Remote control is characterized by a device being operated remotely, either by a human or a computer.

### 2.1.5 Mobile Robotics and Vehicles

Mobile robots and vehicles are playing an increasingly important role in modern factories. This includes mobile units for taking care of the supply of items and material on the shop floor level, such as autonomous guided vehicles (AGVs) or intelligent fork lifters, but also mobile manipulators, which may be flexibly used at different locations and possibly even facilitate a close human-machine collaboration. In general, the performance and efficiency of such mobile units can be significantly increased if they are interconnected with each other as well as the environment using a powerful wireless system. For example, relatively simple and thus inexpensive AGVs may form a larger swarm by coordinating their actions based on information exchanged between them and thus jointly realize complex tasks, such as lifting items that would be too heavy or big for one unit alone. The more reliable and the faster the connectivity is, the safer and faster the coordination can take place. If the wireless system could additionally provide a sufficiently accurate information about the current location of a mobile unit (in the range of 10‑50 cm), this could be beneficially exploited in many cases, for example for autonomous navigation or collision prevention.

## 2.2 Current applications

The following applications are examples for industrial wireless application in general requiring extreme low latency. One of the most important reasons for wireless usage in the industry is the control of moving parts. The traditional solutions are slip rings, or cable chains.

### 2.2.1 Robotic arms

Figure A1-3

Robotic arms

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| --- | --- |
| Data transfer from a moving robotic arm to a control panel has traditionally been a difficult task. A wireless system retrofit installation is the simple solution to many cable-related problems in manufacturing.  Industrial wireless systems must be adapt as requirements and capabilities increase. Constant maintenance and costly shut-downs caused by broken cables are currently being eliminated and replaced with more effective communication solutions. |  |

Figure A1-4

Cable replacement at the welding robot

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| --- | --- |
| **Regular failures of trailing cables**  • Regular failures (every two to three months)  • Specified banding radii for trailing cables cannot be kept  • Signal transmission to the robot gripper is wired in parallel |  |
| **Challenge**  • Existing WLAN infrastructure should not be impaired  • IT requirement = low transmission power = up to 4dBm  • Harsh environment conditions in the welding cell |
| **Advantages of using wireless technologies**  • Fast and low-cost integration into the existing configuration  • No downtimes during production  • No unplanned maintenance intervals anymore  • Robust wireless technology  • IT requirements met with modules having reduced transmission power |

### 2.2.2 Rotating tables/storages

Figure A1-5

Rotating tables/storages

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| To provide continuous sensing of a manufacturing process on a rotation table, without the costly and cumbersome slip-rings required for normally hardwired sensing devices. |  |

Figure A1-6

Wireless control of rotary storage

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| **High costs due to slip ring transmitters**  • Use of noise-prone slip rings  • 6 body rotary storage systems are located in one hall  • Connection to Profibus and the higher-level 97-400 PLC |  |
| **Challenge**  • 2 initiators for each storage location and correct positioning of the body  • 18 storage locations on 3 levels with 6 places for bodies each  • 9 further initiators and limit switches for position detection  • Existing WLAN Infrastructure should not be impaired |
| **Advantages of using wireless technologies**  • Fast and low-cost integration into the existing configuration instead of the slip ring  • No downtime during production  • Robust and reliable transmission method  • Fast replacement of 1/O modules without complicated configuration (just reposition of ID plug) |

### 2.2.3 Overhead conveyer systems

Figure A1-7

Overhead conveyer systems

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| Track the presence/absence of an automobile door on an overhead conveyer, without available DC power.  This sensing system is able to withstand conditions in an industrial environment and will function where other wireless technologies are deployed. |  |
| The wireless nodes on an automotive conveyer communicate with a Gateway located off the chain-driven assembly line. |

### 2.2.4 Other moving parts and applications

Figure A1-8

Moving parts and applications

|  |  |
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| **Measuring data transfer from the hub to pod**  • Recording the bending over strain gauges in the rotor blades  • Measuring device collects the measured values from the rotor blades  • Data is transmitted non-time-critical from the hub to the pod |  |
| **Challenge**  • The rotor hub is made of massive steal  • The massive gear block of the generator is located in the pod  • GFK sheath around the rotor and pod  • No objects may be installed outside |
| **Wireless solution**  • Circular polarized antennas for an optimized wireless signal  • Three antennas are located in the rotor blades to be independent of the blade orientation |

### 2.2.5 Driverless autonomous transportation systems

Figure A1-9

Driverless autonomous transportation systems

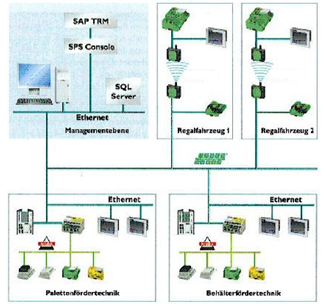
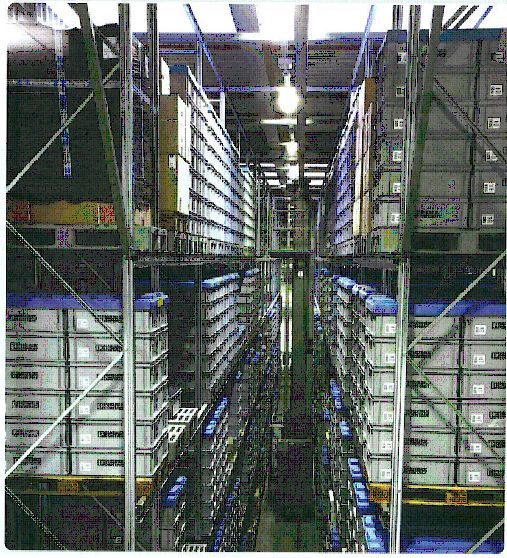
|  |  |
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| The use of AGV (automated guided vehicle) as autonomous transportation vehicles inside a warehouse or factory can facilitate the transfer of manufactures items or other goods like heavy pallets from the factory workstations to the loading dock. In this application the AGVs are moving autonomously through a manufacturing site without interrupting the assembly process. In order to ensure independent and autonomous operation of the vehicles a reliable and secure wireless communication system between the AGVs and a user or a control infrastructure is required (e.g. for sending and receiving the control commands). For this application reliability is crucial, since any longer interruption on the communication network might cause the stop of an AGV which could lead to disruptions in the assembly process.  An example for a currently used wireless communication system for the AGV application is industrial wireless LAN (IEEE 802.11). |  |
| The Gateway and Nodes communicate in a shipping warehouse. |

### 2.2.6 Driverless autonomous transportation systems

The transportation vehicle inside a high rack warehouse needs to get a lot of information from the ERP system. In this application an industrial wireless solution exchanges the data between the moving vehicle and the stationary network.

Figure A1-10

High rack warehouse



### 2.2.7 Crane control

Figure A1-11

Crane control

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| **Locally limited access**  • Connection crane – mobiles maintenance terminal  • Clear, location-dependent  • Service technician has full access to the PLC on site – no need to access the crane |  |
| **Automatic connection setup**  • Automatic connection with crane control when reaching the receiving area |
| **Noise resistant**  • Coexistence of wireless standards |

### 2.2.8 Clean rooms

Figure A1-12

Clean rooms

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| Liquid level measurements must be gathered in an industry-certified clean room. Retro-fit construction and cabling requires re-certification resulting in significant down time.  The fill levels of components for gel cap manufacturing need to be carefully monitored and logged during production to fulfil FDA requirements.  In addition, the measurements recorded need to coincide with the number of batches produced at the end of each process. |  |
| During a gel cap production, the wireless nodes installed near each tank communicate readings from the Fill-Level sensors to the Gateway via RF link. |

### 2.2.9 Refinery and gas production

Figure A1-13

Refinery industry

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| **Application**  Natural gas is needed by users in different amounts at different times. The suppliers need to be able to meet seasonal, weekly and hourly requirement fluctuations. Because the supply of natural gas from imported sources is not particularly flexible, it needs to be stored. Natural gas deposits are the best solution for managing the variation between winter and summer demands. Underground storage in cavities hollowed out of the salt domes hold smaller quantities of natural gas, which can be used compensate for short term demand fluctuations. The natural gas storage facility at Lesum near Bremen is one such underground cavern and along with the facility at Harsefeld bei Stade it is used to supply the consumers around Hamburg, Bremen, Bremerhaven and Cuxhaven on cold winter days. | The monitoring and control of all the operating procedures in the systems is fully automated by a process control system. The system is automatically switched off and made safe if values go above or below specified limit values. Three artesian wells have been installed to monitor the tightness of the underground storage facility. Their pressure values indicate any leaks in the system. If the pressure exceeds a particular limit, this will indicate a leak. |

Figure A1-14

Gas production

|  |  |
| --- | --- |
| **Application**  The development of oil fields in the Emsland region of Germany contributes significantly to raw material and energy supply in Germany. The increasing water cut of the oil fields is a problem for oil production west of Ems – the water content is now around 94 percent. Following separation, this deposit water is transported to the injection pumps. Mixed with fresh water, it is then injected through six water injection wells on the edge of the oil field back into the reservoir rock.  As an important process parameter, the injection pressure at the wells must be monitored continuously. Before converting to wireless technology, the measuring stations for acquiring measured values at the wells were inspected once a day. Now the injection pressure is continuously transmitted via an industrial wireless solution – even when disconnected from the mains. The result is increased safety and efficiency. | In order to transmit the measured values from a wall situated on the northern edge of the field to the central injection pump 600m away, a railroad line had to be crossed.    Before the crude oil is transported to the nearby Holthausen refinery or to the Brögbern pumping station, it must be processed. |

# 3 Characteristics for WIA applications

## 3.1 Operation and maintenance characteristics

### 3.1.1 Ease of use

Communication networks should be able to be planned, set up, operated, and maintained without in‑depth knowledge of communication technologies and with a minimum of time effort. The communication network should provide communication services with clearly defined quality levels, which simply can be used without understanding of how these communication services are realized.

### 3.1.2 Isolation

Many applications, with different QoS requirements, will use the same network. For instance, in a manufacturing environment, industrial control will coexist with the control of autonomous vehicles, manufacturing operations management, video monitoring, building-automation, etc. The priority of these applications from a productivity and safety point of view is often different, and their network resource consumption, too. For instance, monitoring cameras in a factory hall readily surpass the needed network capacity of fire-safety applications, but connectivity for the latter absolutely has to be available at all times. In practice, vertical applications will, at a minimum, be virtually separated from each other. Also, different actors with different roles will need access to the same network. For instance, factory maintenance might be delegated to an external organization, which needs dedicated access to only the machinery it is responsible for. For an appropriate use of the infrastructure, all applications and tenants may not adversely influence each other. For instance, huge communication resource demands for autonomous vehicles may not adversely impact motion control.

### 3.1.3 Multicast

Domain multicast is required for some automation applications.

### 3.1.4 Multi-tenancy

Vertical applications increasingly need to handle different stakeholders who are using the same network for running their services. Examples are operation, maintenance, emergency response, etc. This requirement has to be supported while still assuring the communication service quality level and excluding conflicts between the stakeholders’ interests. This is especially the case if a provider network is used.

### 3.1.5 Network recovery

Not only should it be possible to isolate communication services consumed by different applications and/or tenants against each other (see isolation), but networks should also provide functionality that regulates the network recovery and reconnection of UEs in a controlled fashion. For instance, in a factory setting, after recovery from a network failure, industrial control application should be provided with communication service access before the outbound logistics applications.

### 3.1.6 Quality of service (QoS) description

Distributed industrial solutions do not stop at national or service provider borders. Therefore, a common understanding and definition of industry-grade QoS across national borders and between providers would be helpful. This is the only way to provide service guarantees beyond connectivity in an end-to-end fashion. To assure that such end-to-end services can be setup in a timely manner, fundamental industrial service / SLA profiles including the required monitoring should be available, globally accepted and offered. By so doing, long lasting negotiation periods with several network service operators and undue overhead when merging two networks can be avoided.

### 3.1.7 Service response (Negotiation of QoS levels)

Some automation applications can operate at more than one communication QoS setting. Therefore, if a certain QoS level is requested by the application but cannot be met by the network, an alternative should be proposed by the network. For instance, if the requested end-to-end latency (i.e. the communication service delay from an application point of view) of 10 ms cannot be guaranteed, the communication service indicates what end-to-end latency is instead feasible. The automation application has then the option to request communication services at a refined QoS level.

### 3.1.8 Service deployment time

Today, end-to-end services traversing many network domains, covering large distances or asking for specific quality properties need a long time (in the order of weeks to months) to be setup by the service provider. The reasons for this are suboptimal processes, technical inflexibilities, required manual interventions, missing suitable interfaces, etc. For remote services on demand and many other services this is not acceptable. Significantly reduced lead times of approximately several hours are needed.

### 3.1.9 Simplified approvals

Industrial solutions are foreseen for international use. In many cases, approvals or even certifications have to be obtained before the solutions can be imported and operated. This includes the approval or certification of communication solutions, especially if these solutions leverage wireless interfaces. Region/nation-specific approval or certification procedures which are not mutually recognized, are very cumbersome and expensive. Thus WIA systems should be able to successfully pass such approval or certification processes.

### 3.1.10 Technology availability (long-term availability of technology and the related infrastructure)

The lifetimes of industrial solutions are typically in the range of several decades. In order to ensure continuity, any underlying communication solution has to be available throughout the whole lifetime. Therefore an availability of WIA systems (components, spare parts, and infrastructure) over at least 20 years has to be assured. In this context also backward compatibility is of major importance.

### 3.1.11 Non-standard operating conditions

The absence of low-voltage power supply can be an issue in the field, creating the need for battery- or energy-harvester-powered ultra low-power area networks with a corresponding low bandwidth. For battery powered WIA devices a lifetime of than 10 years (and more) is required.

Harsh environments, including wind and weather, vibrations, heat, dust or even hazardous gases may also be a challenge for communication equipment.

### 3.1.12 Operation of local WIA network infrastructures

Leveraging the full potential of WIA systems can only be achieved if from the very beginning the setup and operation the wireless network infrastructures can be done also in a local and closed environment without the involvement of a 3rd party network provider and without sharing the infrastructure with other (potentially less controlled) users/applications.

The need to keep the operation of local/closed wireless networks in the responsibility of the industrial operator are mainly due to system criticality: the dependence on 3rd parties is minimized, the transparency in the level of compliance with required quality levels is intrinsically given, and responsibilities and liabilities are much easier to determine. All this leads to a significantly reduced risk for the industrial operator. In addition, maintenance strategies of the industrial solutions will be very different to the ones applied by a 3rd party network service operator.

## 3.2 Impact and challenges of radio propagation

The environment of WIA applications typically differs from those of applications in office and urban environments. Industrial environments in general are characterized by large surfaces of metal and cluttered spaces. These industrial environments can be differentiated in indoor environments like factory halls and outdoor environments like process plants.

Factory halls are full of machines, machine centers, stacks of material and shelves, which are in most cases made of metal. Also rooves and walls are often made of or covered by metal. These large amounts of metal surfaces and obstacles cause lots of reflections.

Also in process plants reflections are part of the radio propagation environment. The reflections are generated by tubes and tanks, which can be distributed over large areas.

WIA applications utilise spectrum with different propagation characteristics:

– Spectrum to cover areas also under NLOS conditions:

• Use with moving devices (example: Automatic Guided Vehicles, AGVs);

• Use with small bandwidth and good penetration of walls (e. g. sensors and actuators).

– Spectrum to cover areas under LOS inside production halls, high density of systems (see table [A1-1], Connection density for Factory automation):

• Protection of other systems outside the production halls.

Channel models for these environment would facilitate the development or evaluation of radio systems.

## 3.3 Coverage

In chapter 3 various typical WIA applications are presented. Depending on the application the required transmission range varies between some meters and one kilometer and the coverage between 100 m2 and 1 km2.

Considering range, coverage and additional characteristics the applications are subdivided in three main classes. For detailed values for each class see table A1, row Service Area.

## 3.4 Mobility

WIA systems can be stationary or mobile, depending on the application. Mobile WIA systems can move with up to 50 km/h. Propagation conditions for moving systems can change between LOS, OLOS and NLOS very quickly.

## 3.5 Transmitter parameters

### 3.5.1 Transmitter Output Power/Radiated Power

A maximum transmit output power of 400 mW e.i.r.p. is foreseen for WIA applications.

The value of 400 mW e.i.r.p. is currently established in ERC Recommendation 70-03. This value is required to enable WIA devices to reach the required range (see table A1) also under NLOS conditions and to ensure a reliable transmission.

### 3.5.2 Antenna Characteristics

No restrictions on antenna characteristics.

### 3.5.3 Bandwidth

As different technologies are used, the typical occupied bandwidth for a single device varies between 0.1 MHz and 80 MHz. Specific applications like location tracking may even use the complete available (sub-)band.

Frequency Hopping as well as non-frequency hopping technologies are used.

## 3.6 Channel access parameters

For maximised spectrum efficiency, including sharing among all wireless industrial applications present, a spectrum sharing mechanism may be appropriate for industrial applications.

An example of that is Frequency Agility. Frequency Agility is the ability of a system to operate according to frequency or channel assignments of a centralized or distributed control mechanism, which will define the configuration of all devices within an industrial site or subarea thereof, Configurations may change over time depending on the application requirements. If non-contiguous spectrum is assigned, then the Frequency Agility feature is supposed to operate across all assigned sub-bands.

[Editor’s note: Is there the need additional characteristics? Otherwise delete.]

# 4 Deployment scenarios and architectures

## 4.1 Presentation of system or technology concept

Typical industrial sites are manufacturers of goods or providers at any place within the delivery chain towards these goods (e.g. oil/gas/energy producers, suppliers of parts or components of these goods up to final assembly of the goods, after- production processes such as water/waste management).

Examples of existing communication network solutions are standardized in EN/IEC 61784-2 and EN/IEC 62591 for wireless solutions for so-called PROFINET based on IEEE 802.11/IEEE 802.15.1 and WirelessHART (see EN/IEC 62591) based on IEEE 802.15.4.

Industrial automation requires "robust" wireless technologies to be used for their wireless links in industrial applications. More and more wireless solutions are being considered nowadays for these applications.

The advantages of wireless are savings of often complex and expensive cabling, cable protection and plugs the increased mobility and flexibility as well as the wear and tear free transmission medium. These advantages are particularly high in the area of:

– Monitoring and mobile worker communication.

– Wireless sensors and actuators at moving parts.

Different functions can be mastered substantially more efficient by a wireless network of data acquisition terminals, robotic type equipment or automated guided vehicles.

For the sensor and actuator type of applications in industrial automation, the main requirement is the real time behaviour. Real time means a maximum response time defined by the type of application. E.g. on the factory floor of discrete manufacturing, very short latencies of a few milliseconds and a very high reliability (high robustness) is necessary in order to avoid interruptions in the manufacturing process.

In higher levels of the automation hierarchy e.g. at the control or enterprise level, the data volume rises, so throughput, security and reliability becomes more important, but real–time communication requirements decrease.

To meet these requirements, both application categories require specific wireless technologies for specialised sensor/actuator networks. Some technologies being developed for these applications are listed above.

Industrial automation equipment is typically designed in a way that it is not impacted by other wireless applications present in the industrial environment. If an important wireless link would be interrupted, or not respond instantaneously, appropriate measures will take effect immediately.

To achieve the required performances for different industrial wireless applications, it is important to achieve either short latencies or high throughput, in addition to range and reliability, etc. Therefore, industrial users very much depend on the chosen technical solutions for their seamless operational procedures, i.e. a high dependability is envisaged.

In addition, the manufacturing processes require often to use more than one wireless technology simultaneously within the same area or environment. One option to prevent disruptions by interference is to use a coexistence management system in industrial automation applications according to IEC 62657-2 or using any other appropriate sharing mechanisms meeting the specific demands of the industrial applications.

## 4.2 Deployment scenarios

[Editor’s note: This section is intended to describe the deployment scenarios of subdivisions of WIA system. For example: WIA system deployment in manufacturing cell, factory halls and at plant level.]

In a larger industrial plant, if a chemical or oil-/and gas industry process plant ("process automation") or e.g. an automotive discrete manufacturing plant (discrete or "factory automation"), there are and will be always many different wireless systems and technologies for different purposes in parallel to each other (partly or completely overlapping).

The subdivision of such systems into three main classes can be typically done according to table A1 into:

– cell or sub-unit automation;

Lowest control system level, can be a part of a line in an automotive plant or a normal discrete manufacturing cell or a subunit in process automation (e.g. a reactor with a local control to which sensors and actuators are connected). Typically lower range (e.g. 10 m to 30 m range) but most demanding for latency and robustness, are capable to live with fast movements, integrated antennas and many obstacles (nearly complete shielding).

• One such cell unit has one wireless system with in average 30 devices.

• Up to 10 such units/manufacturing cells can be in close proximity, so that their interference area overlaps.

• The area related local device density at 10 m range therefore is typically 10x30 devices per 10x10 m² or 0,33 to 3 devices per m² (at 30 m to 10 m range respectively).

• The cell automation data packets as such are typically quite small and have 16 octets on air (e.g. 4 octets of user data, 12 octets for addressing, control and error protection) and have to be sent every 50 ms in each direction.

– factory hall or plant sub-unit automation;

Medium Control System level, where e.g.:

a) whole production lines or moving applications (e.g. moving through a factory hall in discrete manufacturing e.g. automated guided vehicles, rail hanging power screwdrivers), or

b) whole production units in process automation:

• Larger area (e.g. 100 m x 100 m) are covered, for example, by an IEEE 802.11 device or a mesh type technology (TDMA schemes used).

• Average of 100 devices with low latencies.

Also here the master uses a higher duty cycles and high power to cover the range without line of sight:

– Up to 5 such independent systems can be within range of each other.

– The area related local device density at 100 m range therefore is approximately 5 × 100 devices per 100 × 100 m² or 0.022 per m² at 100 m range.

– The hall/subunit automation data packets as such are typically medium size with 200 octets on air (e.g. 140 octets of user data, 60 octets for addressing, networking, control and error protection) and have to be sent every 200 ms in each direction.

– plant level automation

Control system level covering up to the whole plant, typically an industrial mesh technology:

Able to cover e.g. 1 km × 1 km but typically with mesh technology to increase robustness against typical industrial influences (moving obstacles, interference).

– One such mesh system can have up to 1 000 connected devices, but each device only having to cover a smaller range (100 m) and the mesh covers the larger distances needed, without excessive power needs.

– There may be up to 3 independent mesh networks operating in parallel in the whole plant. Up to maximum of 50 devices within 3 clusters can be within range of each other.

– The local device density at 100 m range therefore is approximately 50 devices per 100 × 100 m² or 0,025 per m² at 100 m range.

– The plant level automation data packets are typically medium size with 105 octets on air (e.g. 50 octets of user data, 55 octets for addressing, networking, control and error protection) and have to be sent every 500 ms in each direction.

All of these 3 levels are operated in parallel (partially or completely overlapping radio area), and often by different operators and connected to different Control Systems. Each of the many wireless systems has to be allowed to switch on and off and vary the number of connected active devices and data amount transferred, depending of the needs of the many different production cells/subunits/ lines in order to maximise individually production, quality, safety and do service, troubleshooting and installation work on the productions units.

Parallel means that in most parts of the plant the three "wireless" classes have overlapping coverage, preferably in the same frequency band. This provides the opportunity for maximal flexibility of coexistence management, increasing spectrum efficiency, limited-industrial-interference, power efficiency (range) and bending/damping by obstacles.

Figure A1-15

Example of a 1 plant production with 10 production halls and 50 manufacturing cells

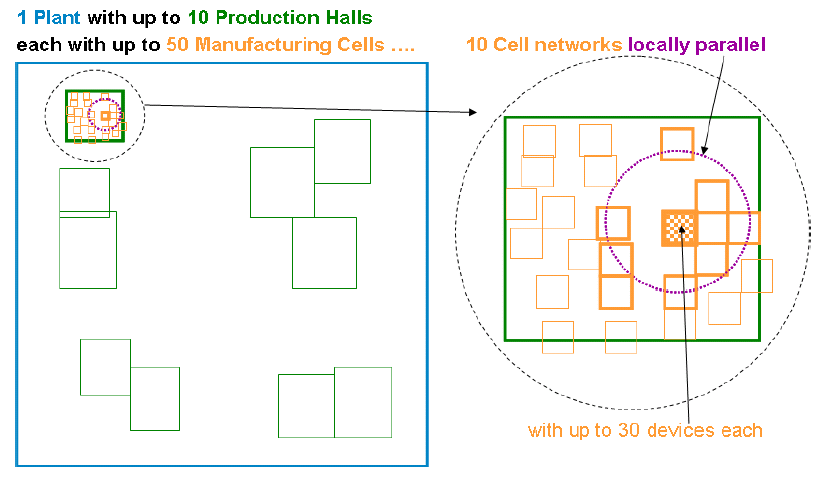


Figure A1.16

Example of hall wide networks, up to 5 locally parallel

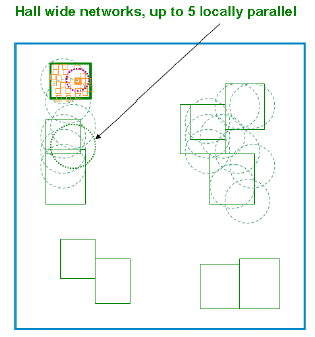


Figure A1-17

Example of plant wide networks, up to 3 parallel

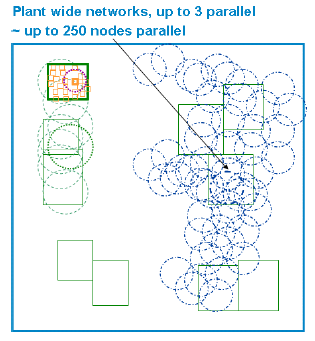


Figure A1.18

Example of a combination of 3 classes

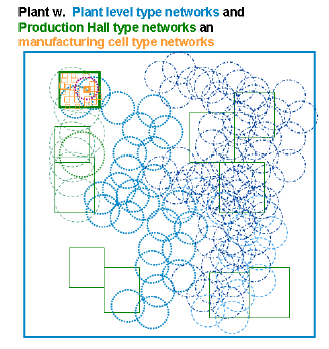


Table A1

Unit density

|  |  |  |  |
| --- | --- | --- | --- |
|  | Manufacturing cell | Factory hall | Plant level |
| Indoor/outdoor application | indoor | mostly indoor | mostly outdoor |
| Service Area L×W×H [m3] | 10 × 10 × 3 | 100 × 100 × 10 | 1 000 × 1 000 × 50 |
| Number of devices (typically) | 30 | 100 | 1 000 |
| Number of parallel networks (= clusters) | 10 | 5 | 3 |
| Number of such clusters per plant | 50 | 10 | 1 |
| Min. Number of locally parallel devices | 300 | 500 | 250 |
| Update time [ms] | 50 | 200 | 500 |
| Network Type | Star | Star/Mesh | Mesh |
| Typical operational distance | Depends on individual use case and frequency of operation. | | |

# 5 Information on spectrum usage for WIA applications

## 5.1 Region 1

In Europe the band 5 725–5 875 MHz is currently already in use by various technologies. These devices comply with current regulation for short-range devices (Decision 2017/1483/EU amending Decision 2006/771/EC, ERC Recommendation 70-03) and typically operate as non-specific short‑range devices.

In Europe the transmit power of devices operating in 5 725–5 875 MHz is limited to 25 mW e.i.r.p. according to Decision 2017/1483/EU, which also limits the range and reliability and thereby also the range of possible applications. [Draft] ETSI EN 300 440 v2.2.0 addresses the technical conditions for the use of this band.

In addition, ERC Recommendation 70-03 includes the possibility to use of this frequency band for WIA applications up to 400 mW, given the implementation of appropriate spectrum access and mitigation techniques. These conditions of use are included in [draft] ETSI EN 303 258 v1.0.6.

Today also RFID systems are being implemented in the band 5 725–5 875 MHz for identification, tracking and real-time location applications. These RFID systems use active tags transmitting with power levels up to 25 mW.

## 5.2 Region 2

[Editor’s note: USA to check the data below.]

[In some Region 2 countries, parts of this 5 725–5 875 MHz band are open for IEEE 802.11 devices. In the USA the band 5 725–5 850 MHz, designated as U-NII-3, is made available to unlicensed devices with a transmit power of up to 1 W e.i.r.p. (FCC 13-22). This frequency range is covered by IEEE 802.11 channels 149 to 165, and vendors are offering chipsets supporting this band additionally to the traditional RLAN bands between 5 150 MHz and 5 725 MHz.]

## 5.3 Region 3

[Editor’s note: No information available.]

Annex X

[Editor’s note: This is a place holder for other industry wireless applications.]