Technology: iPCF-MC – Industrial Point Coordination Function with Management Channel

Abstract

iPCF-MC is a real-time wireless protocol for automation and safety applications.

The protocol is – like iPCF – characterized by a polling mechanism which is optimized for automation traffic. Additionally, iPCF-MCs rapid roaming mechanism leverages a so-called management channel.

It allows for a very flexible scaling of applications in terms of number of participants per AP and also in terms of coverage area from 1 to 1 connection up to the coverage of a whole plants with hundreds of clients.

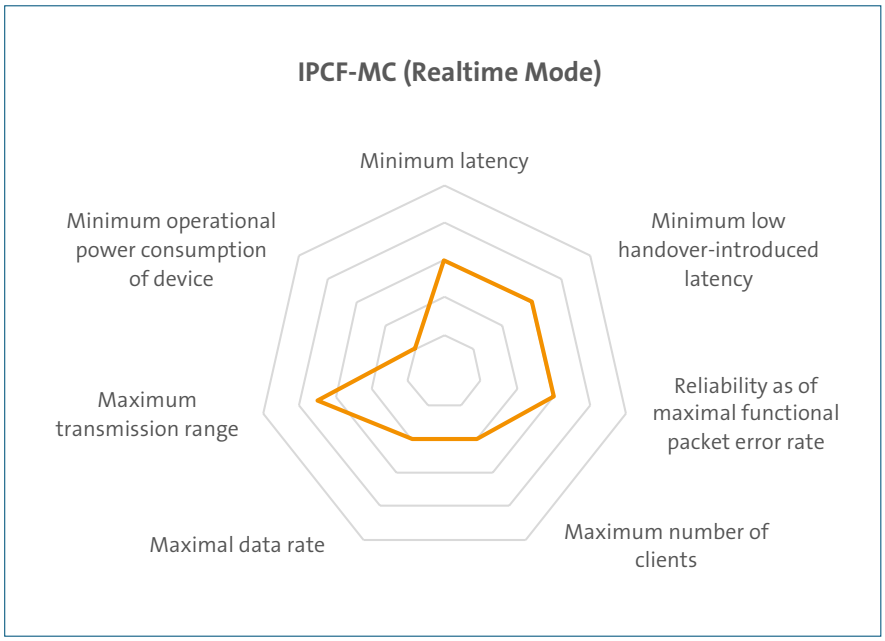
Based on IEEE 802.11 it allows the worldwide usage of 2.4 GHz and 5 GHz frequencies. Mainly operating at layer 1 of the OSI-model it allows the transparent communication of most packet-based protocols like PROFINET/PROFIsafe, Ethernet/IP and also IP based protocols like TCP/IP, UDP, OPC UA and others.

iPCF-MC has specifically been designed for automation applications, including but not limited to

- Wireless real time communication in
  - Industrial production
  - (Intra)logistics
- Wireless safety for programmable logic controllers (PLCs)

The iFeature iPCF-MC can be used in all industries where high availability through real-time communication and safety applications is relevant. iPCF-MC distinguishes itself from iPCF by the use of a management channel to enable sub 50ms roaming times, independent from the number of used channels, it therefore is optimized for the usage with big, free moving applications.

Technology Briefly



Note: Scale value “5” = best performance; scale value „0“ = not specified. Source: Siemens AG

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 topology of an IWLAN iPCF-MC solution consists of one to multiple base stations (Access Points) and one to multiple clients. The Access Points are characterized by the use of two interfaces, one for real time communication (data channel) and one for optimized roaming of clients (management channel).

The range of a single cell, read a single Access Point, is limited by various parameters like building material, antenna used and signal power. To increase the range, several Access Points can be used. The change of a client from one Access Point to another is called roaming. iPCF-MC allows for the scaling of the topology over all available 5 GHz channels without increasing roaming times for the clients.

From a network perspective the wireless link can be handled logically like a cable and therefore easily and transparently integrated into the network. This is due to the proprietary feature “Layer 2 Tunnel”.

Interfaces

Data Interface	**Ethernet-Type Traffic: e.g.,** PROFINET (PROFIsafe) EtherNet/IP (CIP SAFETY) Modbus TCP, OPC UA, UDP, TCP/IP ...
Runtime Interface	Diagnostic information is available during runtime by • Web based Management directly within a browser (WBM) • Command Line Interfac (CLI) • SNMP (Simple Network Monitoring Protocol) • Syslog • Mail (SMTP) • SINEC NMS (central network management system)
Configuration Interface	Configuration can be done through different mechanisms: • WBM • CLI • SNMP • SINEC NMS (central network management system) • Configuration and License PLUG

Source: Siemens AG

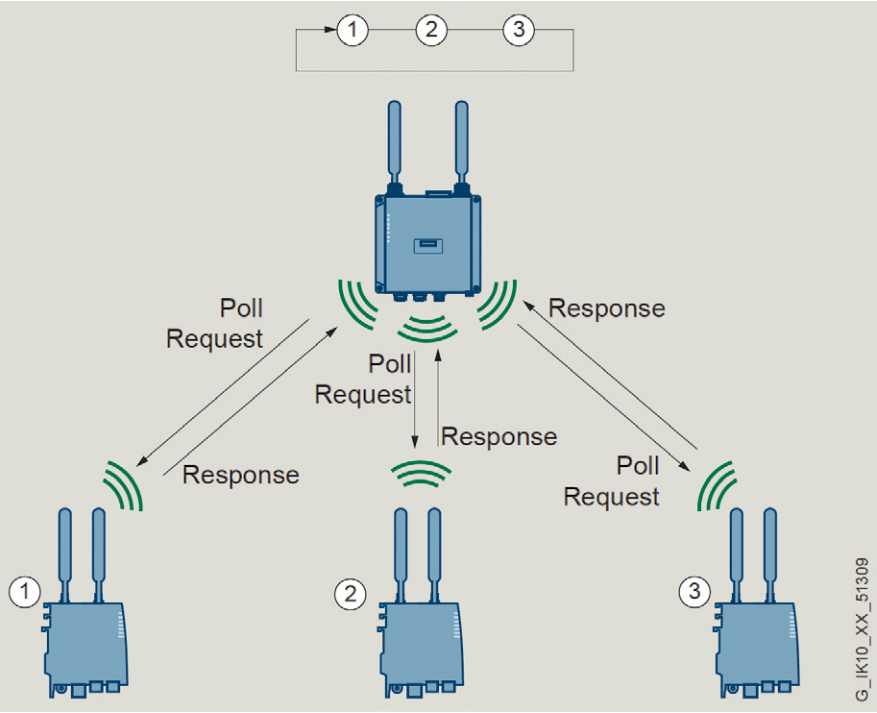


Figure 1: Sketch of polling in iPCF/iPCF-MC Source: Siemens AG

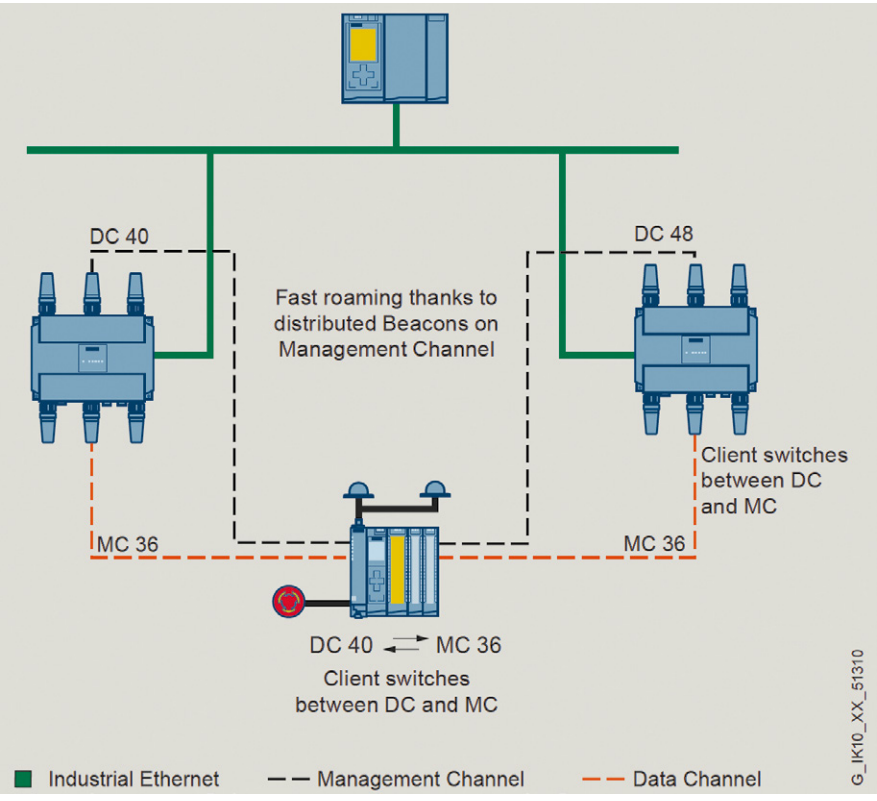


Figure 2: Roaming procedure iPCF-MC. Source: Siemens AG

Time Behaviour

Two main principles enable real time communication with iPCF-MC:

First principle: The cyclic polling of all clients by the Access Point as in iPCF. Each client has a reserved time window for data transmission. This also realizes communication in real time via PROFINET. The data rate can be set flexibly or fixed depending on the application.

Second principle: The iPCF-MC is using in addition to iPCF a rapid roaming based on a management channel, where the clients only need to scan a single channel to decide which Access Point is the right one for them and connect instantly. The roaming time of iPCF-MC is constantly below 50ms instead of the standard WLAN roaming times of up to 100s of milliseconds. Roaming based on the management channel is described in more detail below.

The roaming process in the iPCF-MC procedure is as follows.

- 1. The client and Access Point 1 exchange data via data channel 40.
- 2. During the time outside the polling interval, the client scans the management channel 36. Access Point 1 is received most strongly
- 3. As long as the frames of Access Point 1 is received as strongest AP on channel 36 (the management channel), the communication via data channel 40 continues.
- 4. If the client moves closer to the coverage area of Access Point 2, this is immediately detected on the management channel.
- 5. The client then connects to the Access Point 2 as soon as it's signal is better than Access Point 1. They directly start to communicate via the (new) data channel 48
- 6. The client and the Access Point now exchange data via data channel 48.

Unlike iPCF roaming occurs when the client detects another Access Point with a better signal via its management channel.

Spectrum

The iPCF devices are using the 2.4 GHz unlicensed ISM band and in 5 GHz the unlicensed UNII-1 up to UNII-3.

It usually uses a channel width of 20 MHz.

Coexistence

As the ISM and UNII-bands are unlicensed spectrum the medium access is regulated by national and international organizations.

Common disturbers for real time wireless communication based on iPCF are microwaves or Bluetooth in ISM band or e.g., smart lightning using radar technology in U-NII-3 band.

For the highest performance thorough channel planning within a site must be implemented.

Maturity

iPCF-MC is a protocol already available in the second hardware generation. It's in the market since over 15 years supporting hundreds of different applications and can therefore be seen as mature/proven.

The iPCF-MC protocol is supported within the SCALANCE W700 802.11n product family.

Figure 3: SCALANCE W Portfolio. Source: Siemens AG

Detailed Technology Description

Technical Parameters

Parameter	General KPIs
Protocol	IEEE / proprietary
Frequency bands	2410...2480 MHz 4900...5800 MHz
Un-licensed frequency band	Yes
International coverage	Yes
Real-Time capability	Yes
Network topology	Base station (Access Point)
Handover (mobility) support	Yes
Voice support	Yes
Localization support	No
Coexistence mitigation mode	No
MiMo capability	Yes
Typical range BS - MS	Scalable up to campus covering wirelessly
Typical latency BS - MS	2 ms
Typical data rate	30 Mbps
Maximal number of active clients	256
Maximal lifetime when using a battery	n.s.
Expected interference immunity	poor
Likelihood of coexistence	poor
Signal bandwidth	20 – 80 MHz
Coexistence relevant bandwidth	s.a.
Technology maturity level	Proprietary
Product availability	Available
Standardization	Proprietary
Required Infrastructure on site	Access Points
Realtime Mode	
Nominal latency	64 ms
Handover introduced latency	21.5 ms, always < 50 ms
Cycle time	64 ms
Roundtrip time	64 ms

Parameter	General KPIs
Maximal Functional Packet Error Rate	<10^5
Maximum number of clients	32
Telegram size	up to 1500 Bytes
Maximal data rate MS downlink	1 – 30 Mbit/s (depending on tne # of MSs)
Maximal data rate MS uplink	1 – 30 Mbit/s (depending on tne # of MSs)
Data payload per MS downlink (net)	up to 1500 Bytes
Data payload per MS uplink (net)	up to 1500 Bytes
Maximal RF power [EIRP] downlink	30 dBm EIRP, depending on regulatories
Maximal RF power [EIRP] uplink	30 dBm EIRP, depending on regulatories
Required SNR	30 dB
Mean power consumption in usecase	max. 6 W/MS, max. 11 W/AP
Maximum transmission range	> 1000 m
Maximum velocity of an MS	130 km/h

Technology Description

iPCF is a media access method used in WLANs. This method works with a central station, often an Access Point, to coordinate the access of the individual stations. Central control avoids collisions and therefore packet delay within the communication system.

In polling-based roaming, time-critical data is prioritized to make the best possible use of the available bandwidth by mobile clients. This makes roaming times of significantly less than 50 ms possible. There is also the Management Channel for iPCF (iPCF-MC). For fast roaming, iPCF-MC optimizes the transmission procedure with the help of a management channel. This allows the client to change the Access Point within a short time. This is an important requirement for industrial use.

Application Reference

For Wireless PROFINET applications is iPCF and iPCF-MC a de-facto standard, enabling real time communication for many years.

Official references can be found on the supplier´s sites.

Use Cases are, but not limited to:

- AGVs
- Overhead monorails
- Transportation
- Elevator applications
- Remote control incl. E-Stops
- Amusement rides
- ...

iPCF-MC distinguishes itself from iPCF by the use of a management channel to enable sub 50ms roaming times, independent from the number of used channels, it therefore is optimized for the usage with big, free moving applications.