IQRF® Smarter Wireless. Simply.

IQRF Standard Specification (PREVIEW)

rev: 240303

Specification can be changed without notice

Abstract

Since 2004, MICRORISC s.r.o. and IQRF Tech s.r.o. have developed a low-cost, low-power, two-way, wireless mesh communication technology. Thanks to the 2-decades continuous development for and with our customers, we created state-of-art communication technology for wireless mesh networks featuring values:

- Industrial reliability,
- simple integration,
- ultimate security,
- interoperability and huge ecosystem,
- true low power efficiency.

Dozens of patents were granted, protecting the IQRF® and its implementors from plagiarism and saving their investments.

The IQRF® moves to the third decade as an open standard. This document discloses the specifications needed for the IQRF standard implementation. The IQRF standard implementations and use of all IQRF standard-related essential patents are allowed under a single royalty-free license.

Keywords

Wireless; Mesh; Networks; IQRF; Standard; Open; Free

Patents and licensing

Specific protocols, arrangements, and solutions described in this specification are protected by one or more patents in Czech, EU, USA, China, and Japan. A single royalty-free license allows the IQRF standard implementation and use of all IQRF Standard related essential patents. For details, check the website https://standard.iqrf.org.

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1. DOCUMENT

1.1. HISTORY AND REVISIONS

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1.2. AUTHORS AND CHAPTERS SUPERVISORS

- General concept and the first public release of the Specification
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- Chapter 10 Security specification:
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- Annex A – Region related setup:
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    - The Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science, for cooperation in IQRF-related projects.

1.3. SCOPE

This document contains specifications and descriptions of processes, data structures, security, interfaces, protocols, timings, and algorithms related to the IQRF standard.

1.4. PURPOSE

The purpose of this document is to provide a complete description of the IQRF standard as a basis for implementing interoperable, low-cost, highly reliable, and usable products for wireless mesh applications. Implementations of the IQRF standard shall keep definitions and rules described in this specification, especially data structures, process flows, and timings, to ensure devices interoperability. Implementations, on the other hand, should be optimized for the ported MCUs and radios.

1.5. DESIGN ARCHITECTURE

The IQRF layered architecture design is based on the ISO OSI standard recommendations. Each layer performs a specific set of services for the layer above. Detailed architecture is depicted in Figure 1.

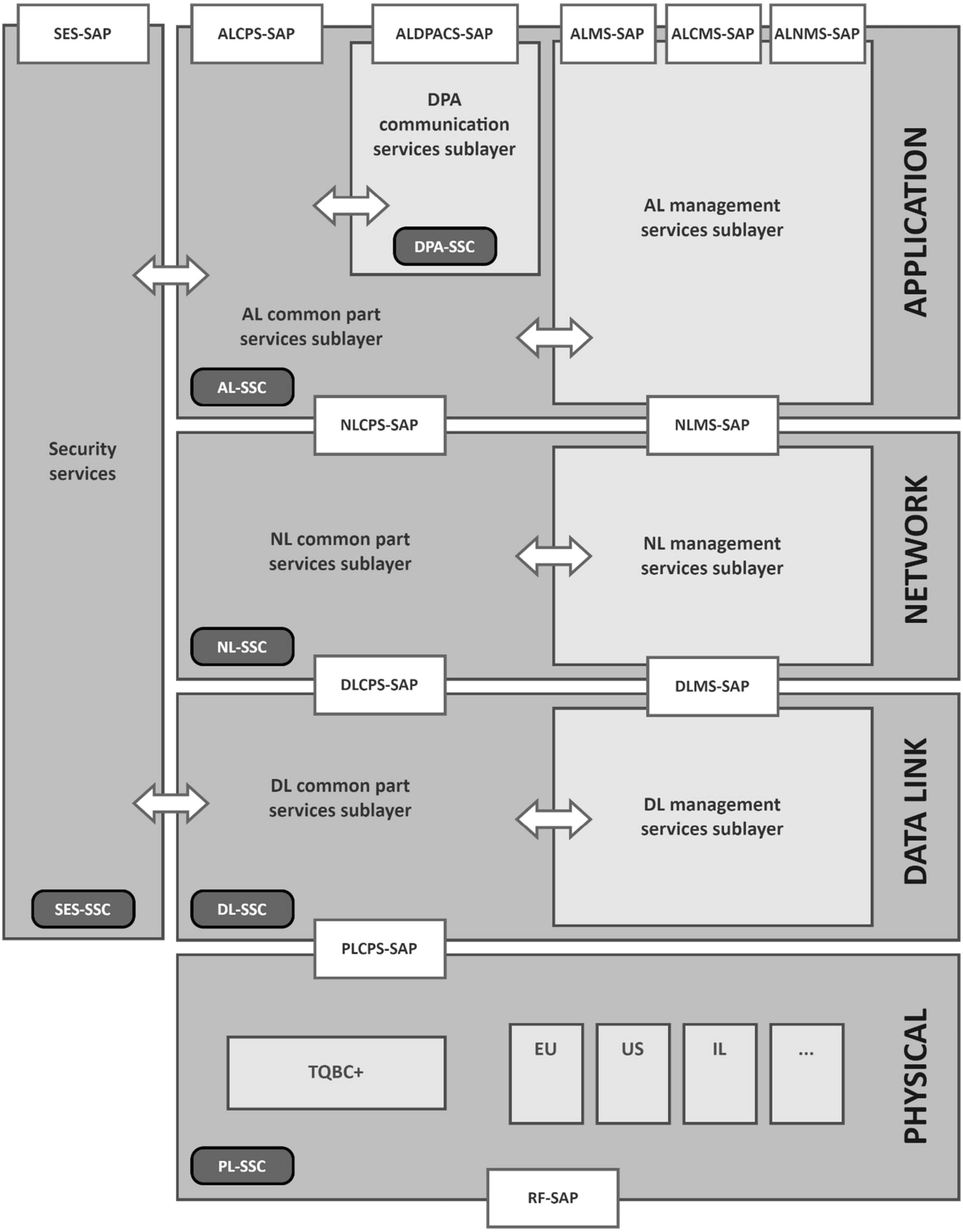


Figure 1: IQRF standard design architecture

1.6. ACRONYMS

AES	Advanced encryption standard
AL	Application layer
ALCMS-SAP	ALMS service access point (coordinator)
ALCPS	Application layer common part services (sublayer)
ALDPACS	Application layer DPA communication services (sublayer)
ALMS	Application layer management services
ALNMS-SAP	ALMS service access point (node)
AL-SSC	Application Layer System Setup and Configuration
ASID	Association ID
ASPS	Association PHY setup
BED	Beaming device (device class)
BEN	Beaming node
BNCK	Base Network Communication Key
CBC	Cipher Block Chaining
CBC-MAC	Cipher block chaining message authentication code
CCM	Counter with CBC-MAC
CRC	Cyclic redundancy check
CSMA	Carrier sense multiple access
CSMA-CA	Carrier sense multiple access with collision avoidance
DFR	Data link footer
DHR	Data link header
DJK	Device joining key
DL	Data Link or Data Link Layer
DLCPS	Data Link Common Part Services (sublayer)
DLK	Data link key
DLMS	Data Link Management Services (sublayer)
DL-SSC	System Setup and Configuration for Data link Layer
DPA	Direct Peripheral Access
F-ASA	ASSOCIATED frame for active association
F-ASP	ASSOCIATED frame for passive association
FCE	Frame Control Element
FCS	Frame control setup
F-JR	JOIN-REQUEST frame
FNF	Fixed network frame
FRC	Fast response command
FRE	Frame element
FRXE	SSC FRX element
FSK	Frequency shift keying
FTXE	SSC FTX element
GFSK	Gaussian frequency-shift keying
IMAC	IQRF MAC address

IQRF-SA	IQRF Standards Association
ISS	IQRF Standard Specification
IUK	Individual unicast key
IWMN	IQRF wireless mesh network
KDF	Key derivation function
LBT	Listen before talk
LPLN	Low power and lossy network
LPRX	Low power receive (mode)
LPTX	Low power transmission (mode)
LSb	Least significant bit
LSB	Least significant byte
MAC	Message authentication code
MAC	Medium access control
MSb	Most significant bit
MSB	Most significant byte
NAK	Network access key
NHL	Next higher layer
NHLE	Next Higher Layer Entity
NHR	Network header
NID	Network identification
NL	Network layer
NLCPS	Network layer common part services
NLL	Next Lower Layer
NLMS	Network layer management services
NL-SSC	Network layer system setup and configuration
NRN	Non-routing node
OFMO	Offline mode
PDU	Protocol data unit
PFR	PHY footer
PHR	PHY header
PHY	Physical or PHY (layer)
PL	PHY layer
PLCPS	Physical link layer common part services
PL-SSC	Physical layer system setup and configuration
PNPS	Particular network PHY setup
PPS	Primitive parameters setup
RF	Radio frequency
RFIC	Radio frequency integrated circuit
RIDX	Rotation index
RON	Routing node
RON/A	RON or RONA
RONA	Routing node with aggregation
ROR	Router (device class)

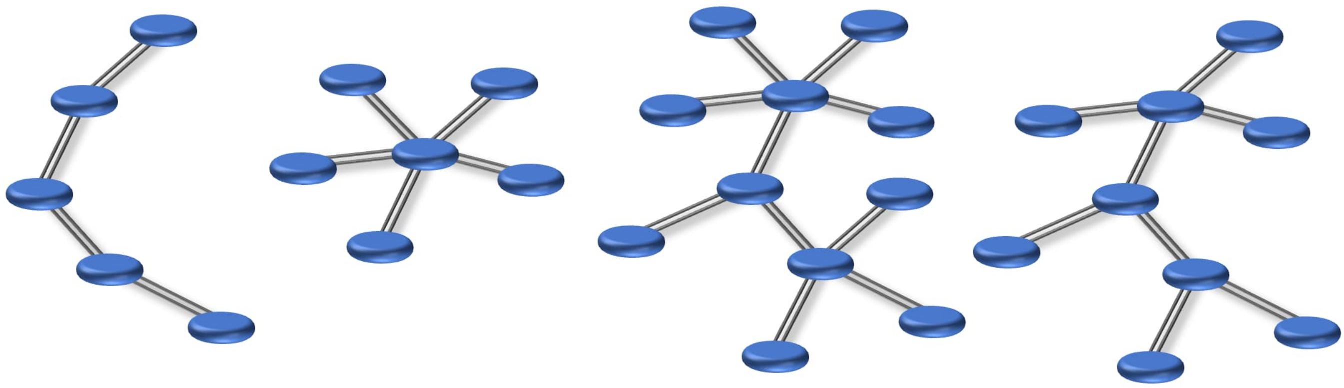
ROR/A	ROR or RORA
RORA	Aggregating router (device class)
RRPS	Region related PHY setup
RRPS	Region related PHY setup
RSSI	Received signal strength indication
RTHR	Routing header
RX	Receive or Receiver
RXMO	Online mode
SAP	Service access point
SES	Security services (layer/block)
SES-SSC	SES system setup and configuration
SNF	Standard network frame (no routing)
SNFR	Standard network frame (routing)
SNNF	Standard non-network frame
SSC	System setup and configuration
SSCE	SSC element
SSC-FRX	SSCE Frame RX
SSC-FTX	SSCE Frame TX
SSCID	SSC element ID
STDRX	Standard receive (mode)
STDTX	Standard transmission (mode)
TDMA	Time division multiple access
TIQBC	Time quanta bit coding
TISS	This IQRF standard specification
TLL	Time-Limited loop
TX	Transmit or Transceiver
VRN	Virtual routing number
WMN	Wireless mesh network
XLPTX	Extra low power transmission (mode)

4. IQRF BRIEF OVERVIEW

Only fundamental principles are described here. A detailed functional description is available in Chapter 11.

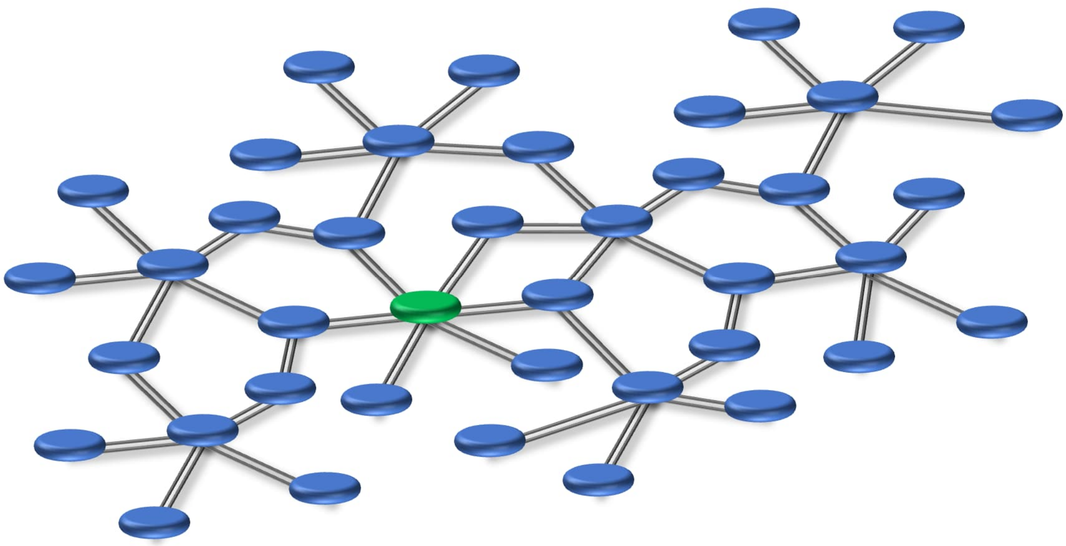
4.1. GENERAL WIRELESS MESH NETWORKS

Wireless mesh networks are a type of network setup that involves multiple wireless router nodes or points spreading across a large area to provide Internet or network coverage. Unlike traditional networks, which rely on a small number of wired access points or wireless routers, mesh networks consist of many wireless nodes that communicate with each other to spread the network coverage over a vast area. This setup allows data to be relayed across the nodes, finding the fastest and most efficient path to its destination. Mesh network topology is the most general network arrangement, including many other distinguished topologies, like the chain, star, or tree. Examples of mesh networks are depicted in the figure below.



4.2. IQRF MESH NETWORK

IQRF networks are organized and orchestrated. The coordinator is such a conductor for other network devices called nodes. Nodes with the routing capability are called routers. The network communication is always encrypted and authenticated according to the latest security standards. The IQRF networks support up to 1024 devices and up to 255 routing hops. Typical IQRF network arrangement is depicted in figure below.



4.3. NETWORK DEVICES

4.3.1. COORDINATOR

Coordinator is a device orchestrating the IQRF network and associating other devices, nodes, to the network. Network address of the coordinator and its Virtual routing number are always 0x00.

4.3.2. NODE

Node is a general device joining the IQRF network.

4.3.2.1. ROUTING NODE

Routing nodes are nodes associated to the network with addresses 1 – 255. Routing nodes participate in the routing and in the aggregation phase of the FRC protocol.

4.3.2.2. ROUTING NODE WITH THE AGGREGATION

Routing nodes with aggregation are routing nodes with the capability of listening to the beaming nodes, store their transmissions and provide requested data from these transmissions through the FRC protocol.

4.3.2.3. NON-ROUTING NODE

Non-routing nodes are node devices associated to the network with addresses 256 – 511. Non-routing nodes are always in receiving and processing incoming transmissions, they do not participate in the routing.

4.3.2.4. BEAMING NODE

Beaming node is a low power node associated to the network with addresses 512 – 1023. Beaming nodes awake periodically or upon defined conditions to transmit their data. Beaming nodes do not participate in the routing and due to the minimizing consumption are not responding to the standard network communication unless they do not switch to the receive mode.

4.4. CREATING THE NETWORK

4.4.1. ASSOCIATION OF JOINING DEVICES

The association is the process controlled by the coordinator and used to establish membership in a network for joining nodes. The coordinator shares bonding information, such as communication keys and network setup, with nodes in a secure way through the encrypted payload and dedicates a unique network address to each node. The IQRF MAC address is used for authentication as a unique identifier of IQRF devices.

4.4.2. DISCOVERY OF ROUTING DEVICES TOPOLOGY

The discovery is the process by which the coordinator discovers routing nodes' topology and dedicates them the Virtual Routing Number, a unique number reflecting distance from the coordinator in hops and defining a time slot during routing.

4.5. NETWORK COMMUNICATION

In most application scenarios, the coordinator initiates communication, and nodes respond through the IQMESH and FRC protocols. Routed networking communication is always orchestrated while beaming nodes transmit their data asynchronously.

4.5.1. DATA AND SYSTEM COMMUNICATION

There are two basic types of communication – data communication and system communication.

Data communication is realized through the standard data frames and enables data delivery to the next higher layer above the application layer.

The system communication supports protocols and functionality described in the IQRF standard specification; the application and lower layers process it, and data are not provided to the layers above the application layer. The system communication is realized through standard non-network, standard networking, and fixed network frames.

4.5.2. COMMUNICATION SECURITY

System non-networking and complete networking communication is always encrypted and authenticated as described in this specification.

4.6. ADDRESSING

The IQRF supports following addressing modes without acknowledgment

- Unicast from the coordinator to any node,
- unicast from the routing node to the coordinator,
- broadcast sent by the coordinator to all network devices,
- broadcast sent by the coordinator or by the node to the neighboring devices,

The IQRF supports following acknowledged addressing modes:

- Broadcast initiated by the coordinator (FRC protocol),
- multicast initiated by the coordinator (FRC protocol),
- selectivecast initiated by the coordinator (FRC protocol),
- broadcast initiated by the node (local FRC protocol),
- selectivecast initiated by the node (local FRC protocol),

4.7. IQMESH® ROUTING PROTOCOL

IQMESH routing protocol is collision-free, based on the TDMA and oriented flooding, supporting unicast, broadcast, groupcast, and selectivecast. It is deterministic and reliable and perfectly works even under challenging environments.

The coordinator detects routing nodes topology during the discovery. Based on the discovered topology the coordinator dedicates the Virtual Routing Number to routing nodes. The virtual routing number is a unique number reflecting distance from the coordinator in hops and defining a time slot during routing. Thanks to the virtual routing number each router knows its position in the network and its dedicated time slot.

TDMA and VRN-based directional flooding guarantees deterministic and collision-free routing.

4.8. FRC® DATA AGGREGATION PROTOCOL

The FRC protocol is based on the IQMESH network arrangements and routing protocol. It enables fast data aggregation and acknowledged broadcasts/multicasts. The FRC protocol further increases IQMESH protocol reliability and provides high-level robustness and successful delivery even under very challenging conditions, being an excellent solution for lossy, low-rate wireless mesh networks.

FRC protocol supports acknowledged broadcast and multicast, and thanks to its high efficiency and reliability, it can be used as an excellent tool for network management.

4.9. IQRF DPA PROTOCOL

Direct Peripheral Access (DPA) protocol is a simple byte-oriented protocol used to control services and peripherals of the IQRF network devices directly from device interfaces such as SPI or UART. IQRF standard specification defines only data communication service support via the DPA protocol. A complete description of the IQRF DPA protocol is available at https://iqrf.org/dpa.

4.10. IQRF SECURITY

The Security Services layer is responsible for ensuring the following security objectives:

- Frame integrity
- Networking frame authenticity
- Footer and Payload confidentiality
- Replay protection

The IQRF uses authenticated encryption with associated data (AEAD) based on the NIST standardized CCM scheme.

17. LIST OF FIGURES

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