

Technology: Mioty, TS-UNB

Abstract

Mioty is a low power wide area network (LPWAN) protocol based on the Telegram-Splitting Ultra narrowband (TS-UNB) radio protocol specified in ETSI TS 103 357. It is operated in the license free sub-GHz bands for short range devices (SRD-bands). The worldwide operating spectrum ranges from 860 to 960 MHz.

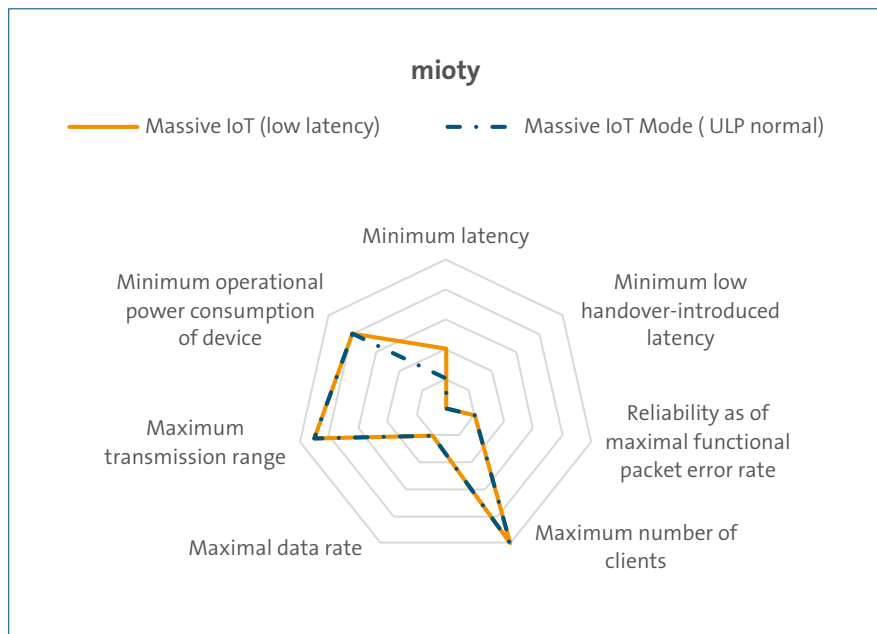
The modulation and coding scheme of mioty allows very efficient spectrum usage with long range communication and battery lifetimes of more than 10 years or energy harvesting operation. It uses state of the art MSK (Minimum Shift Keying) modulation to run on many existing sub-GHz radio chipsets. The new channel access protocol Telegram Splitting Multiple Access (TSMA) specified in TS 103 357 in 2018 offers ultra-reliable communication in contention-based radio spectrum and maximizes the network capacity for a massive number of IoT devices.

Mioty is a LPWAN technology with technology specific benefits within this technology group.

Mioty networks are star networks, where many end-points are connecting to one or more base stations managed by a network management server. The end-points are sensors or actors with small data payloads, typically below 200 byte and with no strict latency requirements. Unidirectional and bidirectional communication is possible, where any communication is triggered by the end-point. When comparing to Wi-Fi 4, the technologies differ strongly, therefore the technologies are supposed to work in complete different applications.

Mioty is hosted by the mioty alliance, which is a non-profit organization based in Germany (www.mioty-alliance.com). The organisation was founded in December 2019 and cares for the standardization of the mioty technology worldwide to make it an open standard in IOT.

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

Mioty is a star transmission topology. The end-point sends its encrypted payload to one or more local base stations that are in the coverage area. A base station is used to receive data from multiple end-points.

The base station transfers the sensor payloads to a server, a so-called mioty Service Center, through an encrypted and secured communication channel (TLS socket).

The Service Center is responsible for the packet deduplication (same payload received from multiple base stations), end-point authentication/subscription and base station management.

The Service Center sends the payloads to the Application Center which is responsible for the payload decryption.

The Application Center delivers the decrypted payload to the IoT platform owned by the end-customer. For security reasons, the Application Center role can be implemented in the end-user infrastructure to ensure end-to-end encryption.

Interfaces

All network internal interfaces between mioty components (Base Stations Service Center Interface and Service Center Application Center Interface) are defined by the mioty alliance and make

use of encoded JSON/MessagePack messages sent over a persistent transport layer security (TLS) connection that provides both encryption and authentication.

The communication between the Application Center and the IoT Platform depends on customer requirements. Commonly used protocols are secure WebSocket, MQTTS, TLS sockets, HTTPS Push as well as integration with common IoT platforms as an example MICROSOFT AZURE or AMAZON AWS.

Time Behaviour

Since mioty operates in the license free spectrum like other LPWAN systems, there are strong limitations in regards of airtime usage. For Europe and other regions, a 1 % limitation applies for end-point devices and 10 % downlink airtime for base stations. This might limit the overall network capacity. Mioty also encounters an inherent limitation for any transmission of approximately 10 % due to the TSMA approach with short radio bursts of approximately 15 ms and long recovery times of 160 ms in average.

Mioty currently defines two classes of devices. Class Z is intended for uplink only applications such as metering and allow for immediate asynchronous update messages from an end-point to the base station at any time. Class A devices are backward compatible with Class Z and incur all the benefits but have an extended feature set that allows for energy efficient uplink acknowledgment as well as uplink triggered downlink of backend data.

A standard uplink message with up to 10 user bytes for both classes has a duration of approx. 3.7 seconds with an on-air ratio of 10 %. A large message of 100 bytes will take around 19 seconds. For class A devices that request an acknowledgement (ACK) including the authorization (AUTH) or receive additional user downlink data, a static response delay of approx.

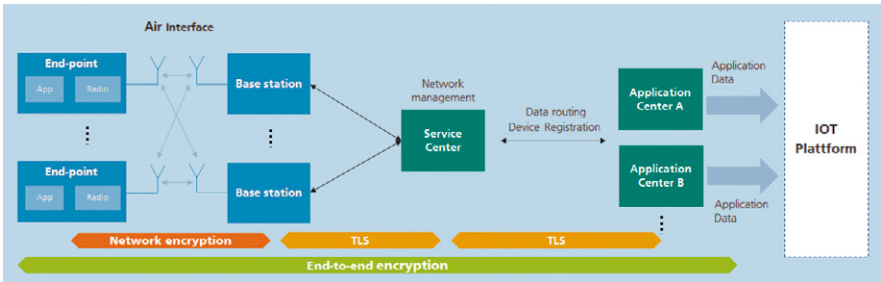


Figure 1: This figure shows the mioty® network architecture. The dataflow is from the endpoint on the left side to the IOT platform on the right side. The communication path is encrypted in two ways, first the network encryption showed in red, followed by the end-to-end encryption from the sensor up to the customer application. The green parts are behind the backend inside of the IT infrastructure and those parts are also described in the mioty standard.

Source: Fraunhofer IIS

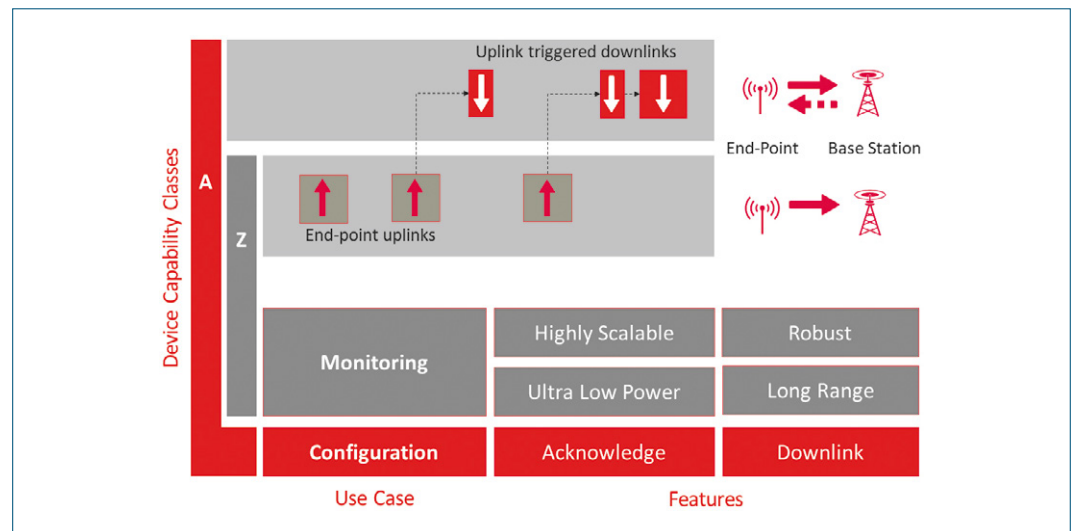


Figure 2: mioty® device class Z and A principals, features and use case.

Source: Swissphone

7 seconds is used before a downlink window opens. Any backend system must be able to process the request and provide downlink data within this given time. This leads to a total round-trip delay of around 12.4 seconds for an acknowledged uplink and approx. 18 seconds to receive up to 24 bytes of downlink data in return using one of up to eleven extension frames.

The base station can manage overlapping up- and downlink messages from and to different endpoints simultaneously thanks to the TSMA quasi-duplex operation and benefit from the high packet redundancy.

The default TSMA mode for mioty is Ultra Low Power (ULP) but it also features a low latency uplink pattern (LL). This approach reduces the

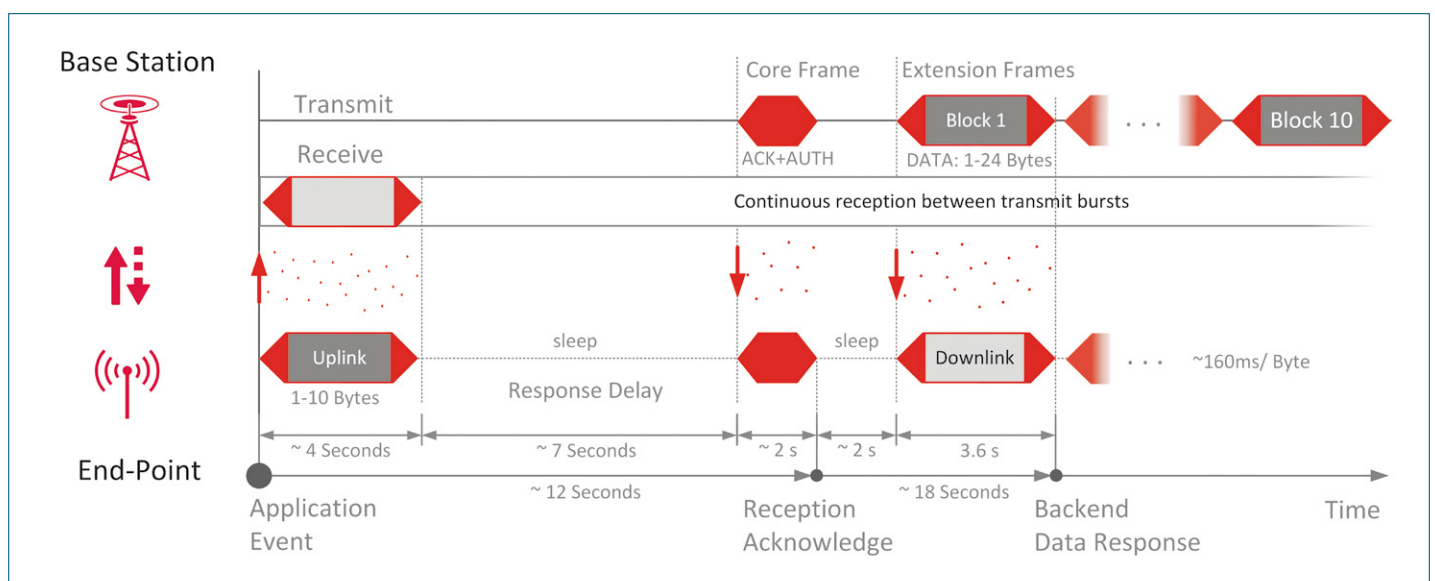


Figure 3: Typical communication timing for mioty class A uplink with requested downlink.

Source: Swissphone

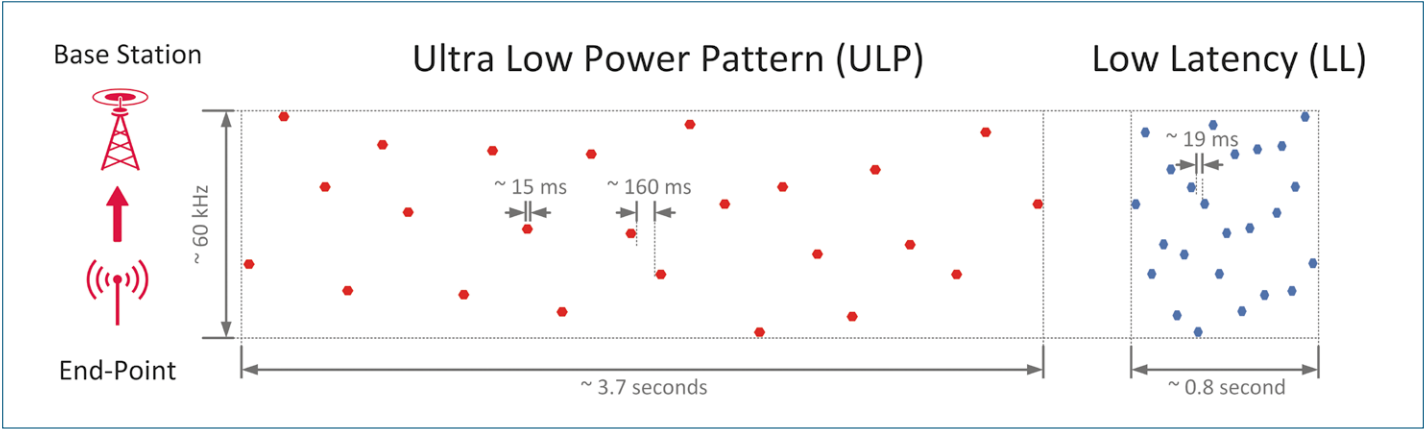


Figure 4: Standard uplink radio core frame radio pattern comparing ULP and LL mode. Source: Swissphone

space between the radio bursts and therefore the message time by a factor of 4.6 while still allow a very high capacity of approximately 1.2 million messages per day and base station compared to 3.5 million for ULP at only 1 % packet error rate statistically.

Spectrum

Mioty uses a narrowband GMSK modulation with a symbol rate of 2380.371 Sym/s and is operated in sub-GHz unlicensed bands worldwide:

Europe	868 - 870 MHz and 433 - 434 MHz
US	902 - 928 MHz
China	470 - 510 MHz
India	865 - 868 MHz
Asia-Pacific	915 - 928 MHz

The modulated carriers are distributed over an operating bandwidth of typically 200 kHz, in countries with dedicated FHSS regulations like USA the operating bandwidth is 1500 kHz. For each region, dedicated profiles are defined respecting local regulations and other radio systems.

Mioty supports licensed frequency operation, too.

Coexistence

Mioty uses the new, innovative TSMA approach which is superior to other random channel access protocols like ALOHA or Slotted ALOHA with respect to network capacity. It can handle collisions from many transmitting devices in a single channel more efficiently. Thus end-points can send data at any time without synchronization or link adaptation with the base station.

Mioty fully complies with common ETSI and FCC requirements such as duty cycle and dwell time. No explicit mechanism other than duty cycle limitations are necessary to keep a high coexistence level, e.g. Listen Before Talk (LBT) or Adaptive Frequency Agility (AFA).

If several end-points send data at the same time, no complete message loss will usually happen due to the multi-dimensional randomness of the hopping sequence using different time slots and frequency channels for each short sub-burst as well as enough time in between the bursts.

The following drawing illustrates this with four end-points transmitting simultaneous uplinks of a core frame. A sub-packet loss of up to 50 % can be corrected by the base station using advanced signal decoding.

Maturity

The mioty technology is based on the TS-UNB radio protocol specified since June 2018 in ETSI TS 103 357 as part of the ETSI Low Throughput Network (LTN) standardization work. The mioty alliance is taking care about the definition of end-to-end solutions and the interoperability of mioty products offered by the industrial mem-

bers of the alliance. The mioty alliance is also taking care about specifications complementing the ETSI specification TS 103357 and is working on enhancements of the technology for future use cases.

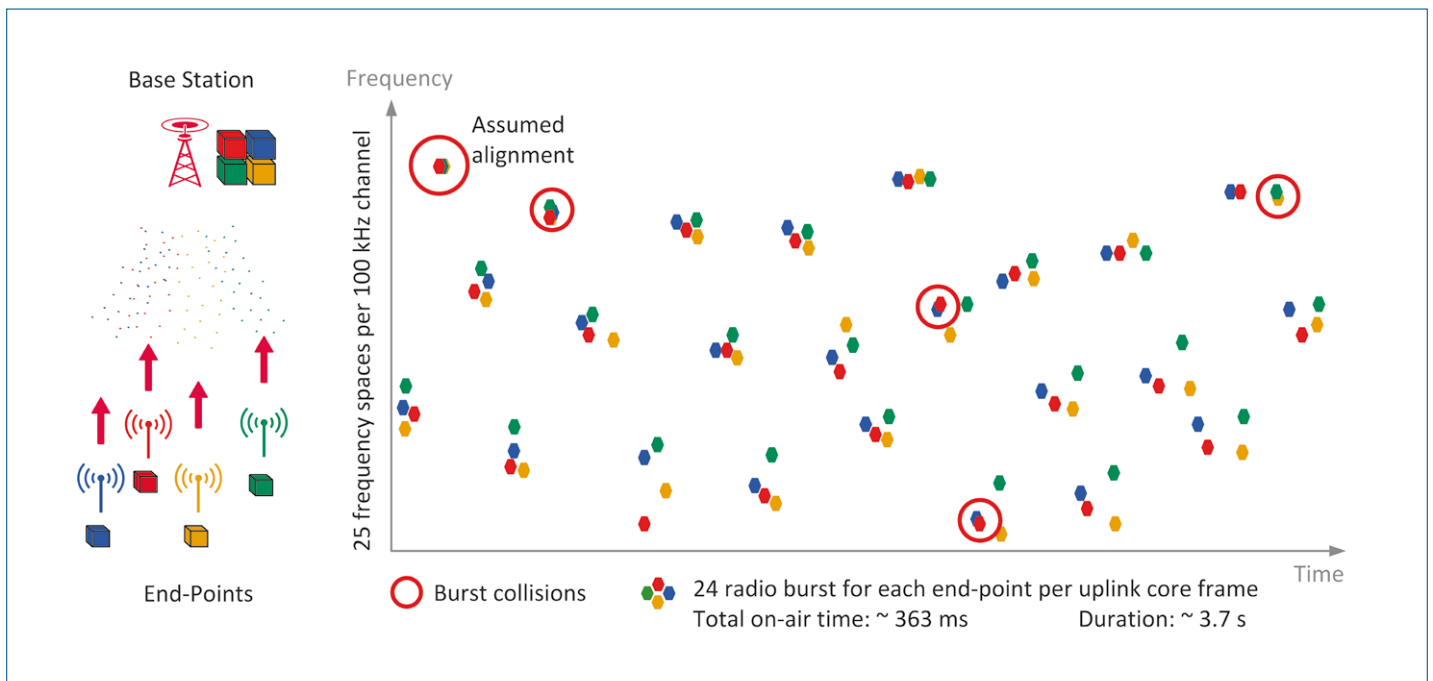


Figure 5: Visualization of mioty telegrams coming from four endpoints to the base station. Randomized pattern sequences are used to minimize possible packet burst collisions (red circles). Source: Swissphone

Detailed Technology Description

Technical Parameters

Parameter	General KPIs
Protocol	ETSI LTN, TS-UNB
Frequency bands	Sub-GHz Bands 868 / 915 MHz
Un-licensed frequency band	Yes
International coverage	Worldwide 860-960 MHz SRD Bands
Real-Time capability	No
Network topology	Star
Handover (mobility) support	Yes
Voice support	No
Localization support	Yes
Coexistence mitigation mode	TSMA: Frequency hopping approach with duty cycle limitation
MiMo capability	No
Typical range BS - MS	Up to 15 km
Typical latency BS - MS	Typ. 3.7 s
Typical data rate	512 Bit/s
Maximal number of active clients	Depends on traffic; over 3.5 million clients per base station with one 10 byte transmission per day
Maximal lifetime when using a battery	Up to 20 years
Expected interference immunity	Good
Likelihood of coexistence	Good
Signal bandwidth	3 kHz
Coexistence relevant bandwidth	200 kHz / 1500 kHz
Localization accuracy	300 - 500 cm
Technology maturity level	New
Product availability	2020
Standardization	ETSI, mioty alliance
Standard availability	2018
Required Infrastructure on site	Base station
Massive IoT Mode (mIoT) - mioty low latency mode	
Nominal latency	0.81 s
Handover introduced latency	n.s.

Parameter	General KPIs
Cycle time	0.45
Roundtrip time	9.5 s
Maximal Functional Packet Error Rate	10^{-2}
Maximum number of clients	Unlimited
Telegram size	20 Byte
Maximal data rate MS uplink	245 kbps
Data payload per MS downlink (net)	1 – 250 Byte
Data payload per MS uplink (net)	10 – 245 Byte
Maximal RF power [EIRP] downlink	29 dBm EIRP
Maximal RF power [EIRP] uplink	16 dBm EIRP
Required SNR	-2 dB
Mean power consumption in usecase	35 mWs
Maximum transmission range	15 Km
Maximum velocity of an MS	120 km/h
Massive IoT Mode (mIoT) - mioty ULP normal mode	
Nominal latency	3.7 s
Handover introduced latency	n.s.
Cycle time	0.01
Roundtrip time	12.4 s
Maximal Functional Packet Error Rate	10^{-2}
Maximum number of clients	Unlimited
Telegram size	20 Byte
Maximal data rate MS uplink	245 kbps
Data payload per MS downlink (net)	1 – 250 Byte
Data payload per MS uplink (net)	10 – 245 Byte
Maximal RF power [EIRP] downlink	29 dBm EIRP
Maximal RF power [EIRP] uplink	16 dBm EIRP
Required SNR	-2 dB
Mean power consumption in usecase	35 mWs
Maximum transmission range	15 Km
Maximum velocity of an MS	120 km/h

Technology Description

Mioty is the implementation of the Telegram Splitting Ultra Narrow Band (TS-UNB) radio protocol defined in the technical specification ETSI TS103 357 and is developed as a LPWAN with star topology approach using TSMA. TSMA is random channel access method wherein the radio transmission of a packet is divided into several short radio-bursts, which are sent discontinuous over the radio channel with transmission free time intervals in between. The radio-bursts are pseudo-randomly distributed over time and frequency within a radio frame. This method offers high interference resilience against radio transmissions of other radio devices, either from own or foreign radio systems, since only a part of the radio-bursts needs to be received by the base station to decode the transmitted payload.

Randomness is achieved by crystal reference tolerance, additional message dependant frequency offset and random channel access in time due to the asynchronous mode of system operation. The start of communication is initiated by the end-point at any time transmission data is available. No network synchronization is needed. The protocol supports Class Z (uplink only) and Class A (bidirectional) end-points. The downlink communication is triggered by an uplink transmission. After the reception of an uplink transmission, the base station may send a downlink transmission after a defined period of time.

To further keep transmission duration short, especially for battery or energy harvesting operated end-points, channel coding together with coherent MSK or GMSK demodulation is used to increase the sensitivity in the receiver to a level of -139 dBm without narrowing the signal bandwidth too much. Hence for the transmission of application data with a size of 10 bytes, the accumulated on-air radio transmission time is less than 400 ms. Therefore, mioty offers ultra-low power consumption down to 35 mWs per message in the end-point and can be operated also in a low-duty cycle band (DC=0.1 %). Due to the ultra-narrowband and short-time transmission as well as the high interference resilience mioty can reliably handle a network capacity of more than 3.5 million messages per day and per base station within a 200 kHz spectrum.

Mioty is capable of handling variable application data with a length of up to 245 bytes in uplink and up to 250 bytes in downlink. The protocol is optimized for an application data length of 10 bytes, which builds the core frame of the TS-UNB protocol. Data is encrypted with AES128. For authentication and integrity check a 32-bit Cipher-based Message Authentication Code (CMAC) is added to the MAC Protocol Data Unit. A 24-bit packet counter is used for replay protection. An optional variable MAC mode can be used for user specific MAC functionalities. Source: ETSI TS 103 357 V1.1.1 (2018-06) "Short Range Device; Low Throughput Network (LTN); Protocols for radio interface A" Chapter 6.1.1

Application Reference

Application Specific Technology Description

Typical applications are low power, robust massive IOT, Industrial IOT, Metering and Smart Cities.

Collecting small amounts of data through wide distributed (rural) areas is crucial to solve a wide range of upcoming new applications in different verticals. Famous applications in this regard are for example metering data, smart city concepts, smart home/building or even the digitalisation of the factory for I4.0. Many approaches today try to use existing wireless networks to collect data points from sensors, but the hurdle here is to not disturb the existing infrastructure with the additional network traffic too much, as well as to use a wireless technology, which fits to the application needs thinking of power consumption,

coverage or the politeness to other existing technologies. Especially when the application has explicit dense networks, the requirement on the required radio technology gets even more important. Mioty is able to digest up to 3.5 million clients per day with very small payloads (10 bytes). Through its many small enhancements, mioty is a very good fit in rough and harsh applications, which have not been resolvable with other technologies yet.

This helps mioty to fill in the gaps in wireless applications, where other technologies could not make a stand in the past.