

SISTEM KOMUNIKASI NIRKABEL

MODUL 7

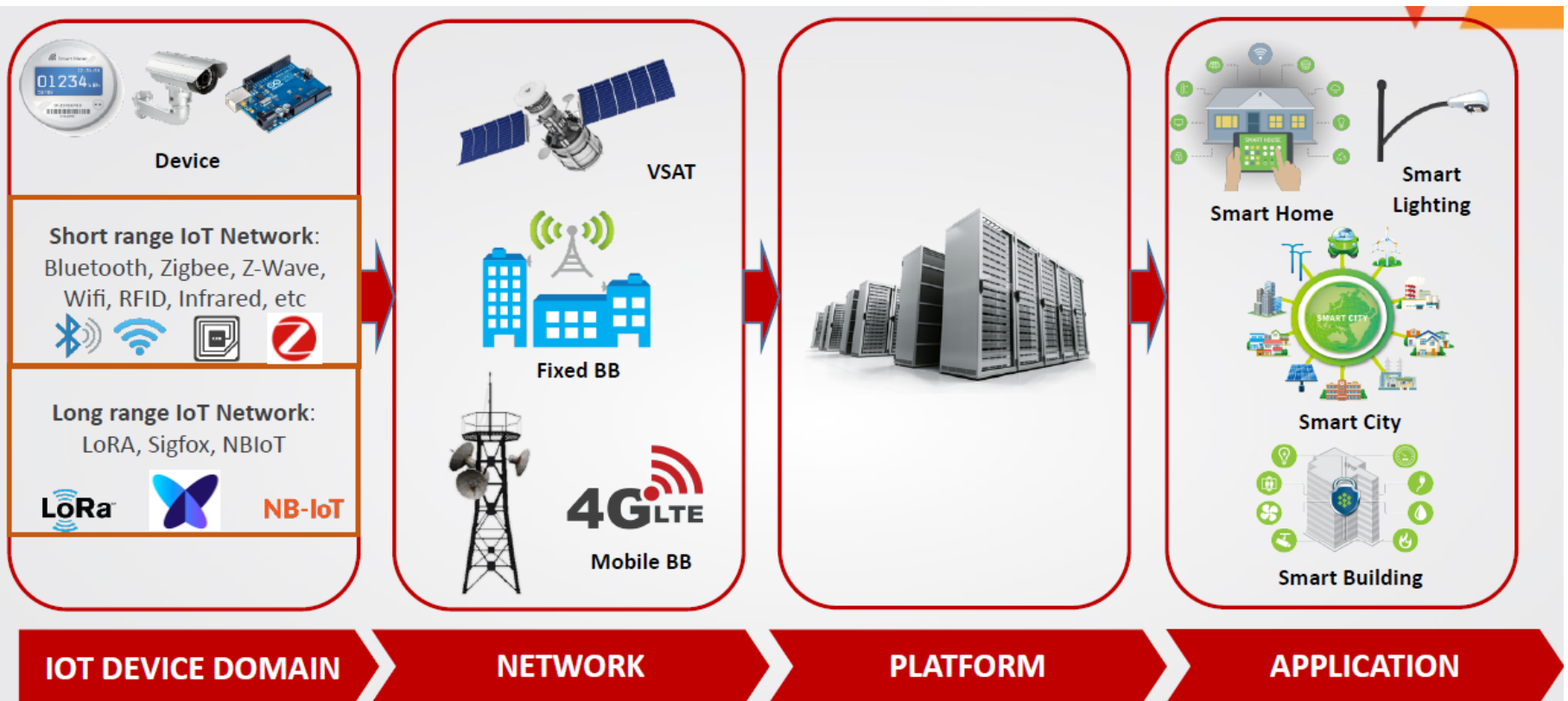
TEKNOLOGI LORA

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TOPIK BAHASAN

- Teknologi LoRa
- Cara Kerja LoRa
- Use Case LoRa

Arsitektur Internet of Things (IoT)

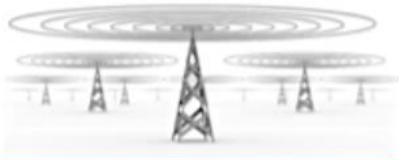


- The use of **Short Range** IoT Network depends on the characteristics and range needed.
Bluetooth (IEEE 802.15.1): Low power, Range 50m, 300 kbps.
Zigbee (IEEE 802.15.1): Low power, Range 10m, 250 kbps.
Wifi (IEEE 802.11.n): Middle power, Range 100m, 150 Mbps.
- For **Long Range** IoT Network, it tends to use unlicensed technology (LoRa, Sigfox).
LoRa: Open system, ISM band, low power, range 15 km, 10-100 kbps, nation-wide and private area.
Sigfox: Proprietary system, ISM band, low power, range 15 km, 100 bps, nation-wide approach.

Apa itu LoRa?

- PHY radio protocol untuk IoT
- Turunan dari Chirp Spread Spectrum
- Didesain untuk long range, low power, low data rate
- Star topology (bukan mesh atau p2p)
- Kecepatan: bps sampai kbps
 - Tergantung pada kedalaman kanal dan modulasi

Apa itu LoRa?



Long Range

- Greater than cellular
- Deep indoor coverage
- Star topology



Max Lifetime

- Low power optimized
- 10-20 year lifetime
- >10x vs cellular M2M



Multi-Usage

- High capacity
- Multi-tenant
- Public network
- Private network



Low Cost

- Minimal infrastructure
- Low cost 'things'
- Open SW



True Location

- In/out door
- Accurate



Bidirectional

- Bidirectional
- Scalable Capacity
- Broadcast



Global Mobility

- True Mobility
- Seamless
- Roaming



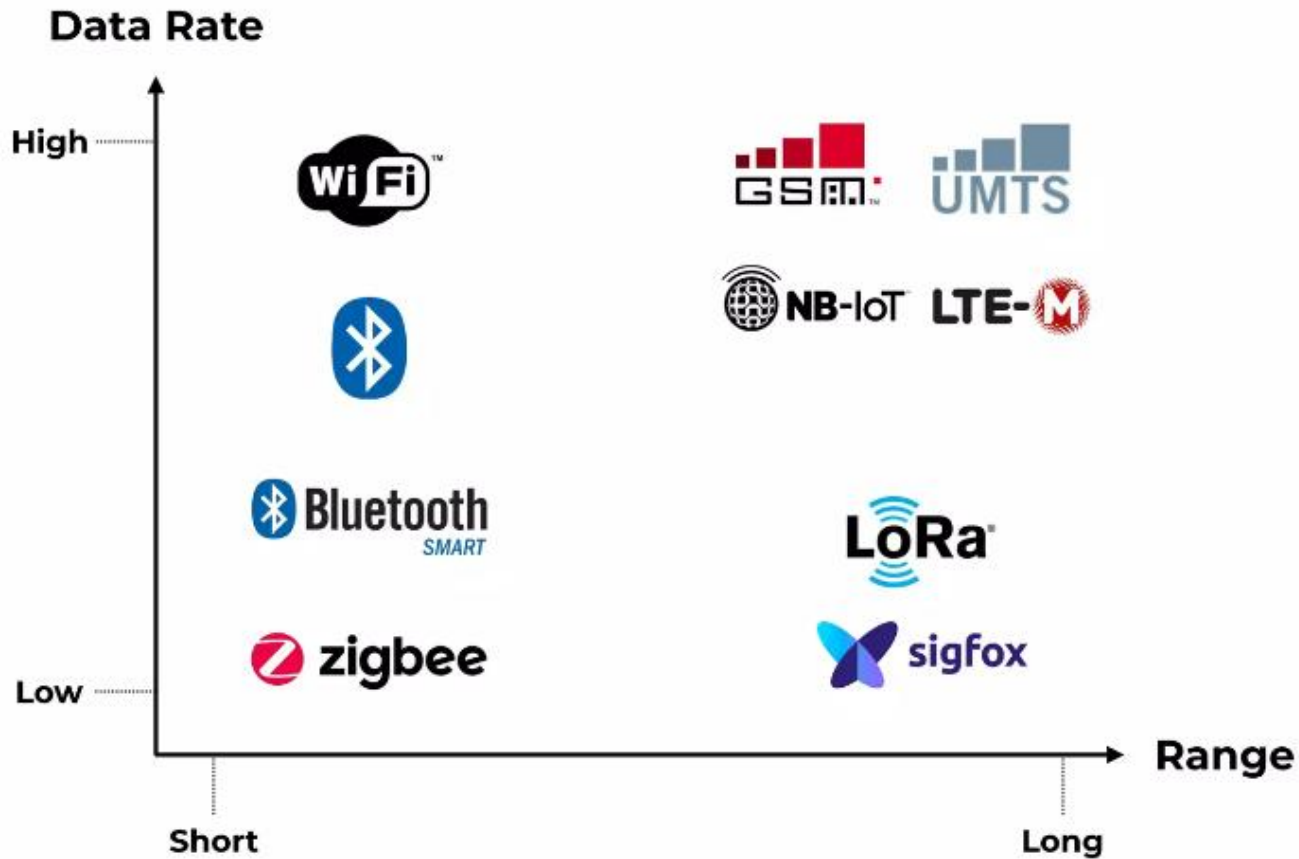
Security

- Unique ID
- Application
- Network

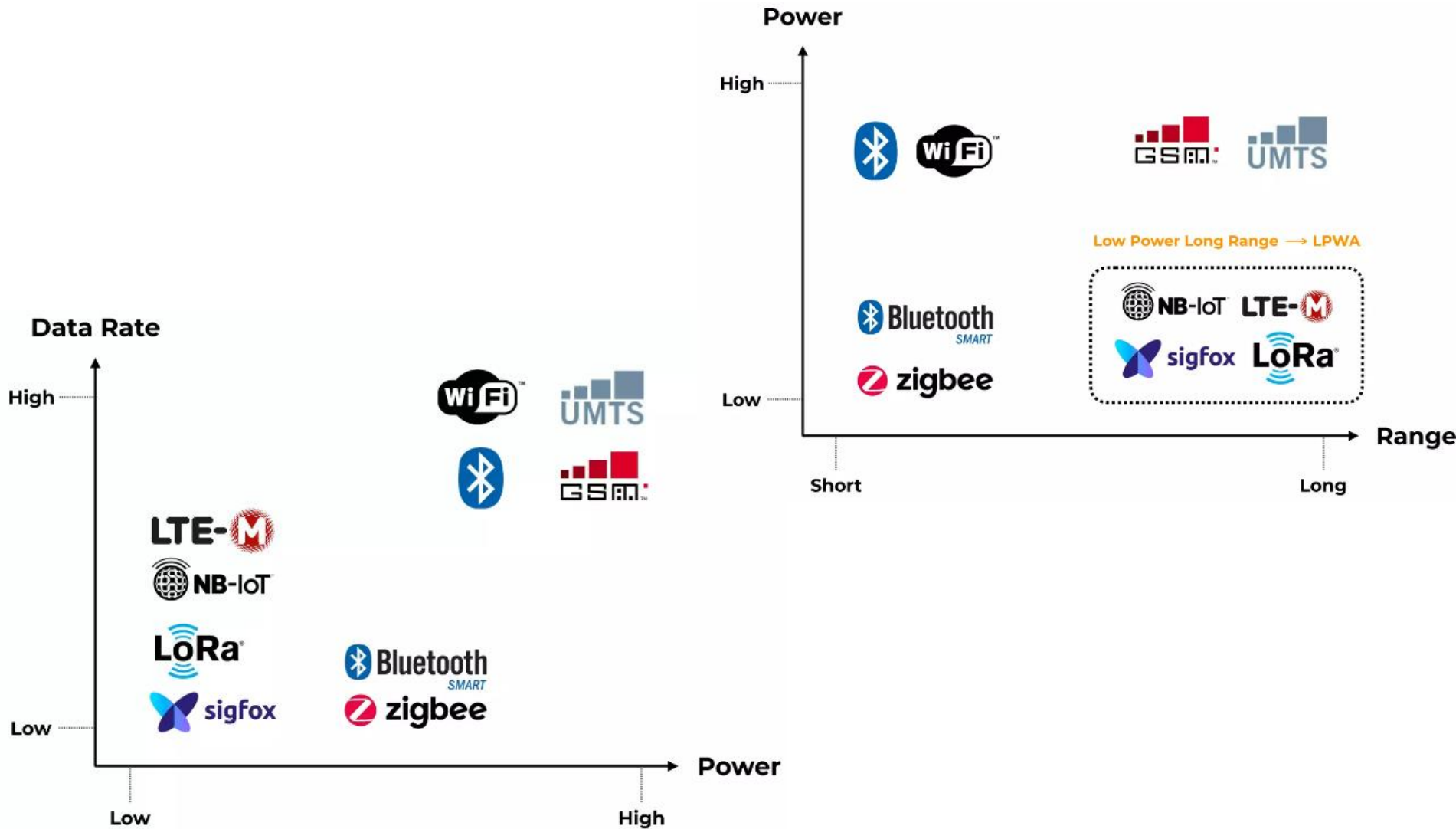
Apa itu LoRaWAN?

- Jaringan nirkabel untuk IoT: menghubungkan 100k~300k node
 - Open, non-proprietary standard
- Menambahkan pengalamatan, *mobility* dan lokalisasi
- **Multiple base station** dapat menerima dan memproses paket
- **Adaptive data rate schema** untuk meningkatkan unjuk kerja
- **Multiple level** dari enkripsi (network dan aplikasi)
- Mendukung *time slot scheduling* dari transmisi perangkat
- **Robust communication**: tidak interferensi dengan WiFi, Bluetooth, GSM, LTE, dll
- Arsitektur LoRaWAN berdasarkan RFC 8376
 - <https://datatracker.ietf.org/doc/rfc8376/>

Data Rate vs Range



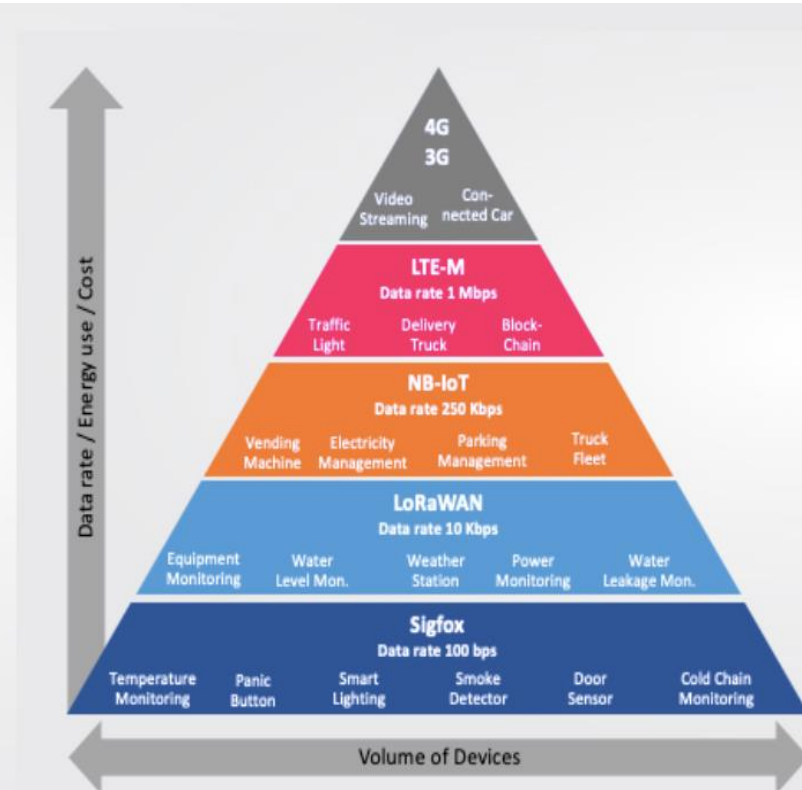
Data Rate vs Power vs Range



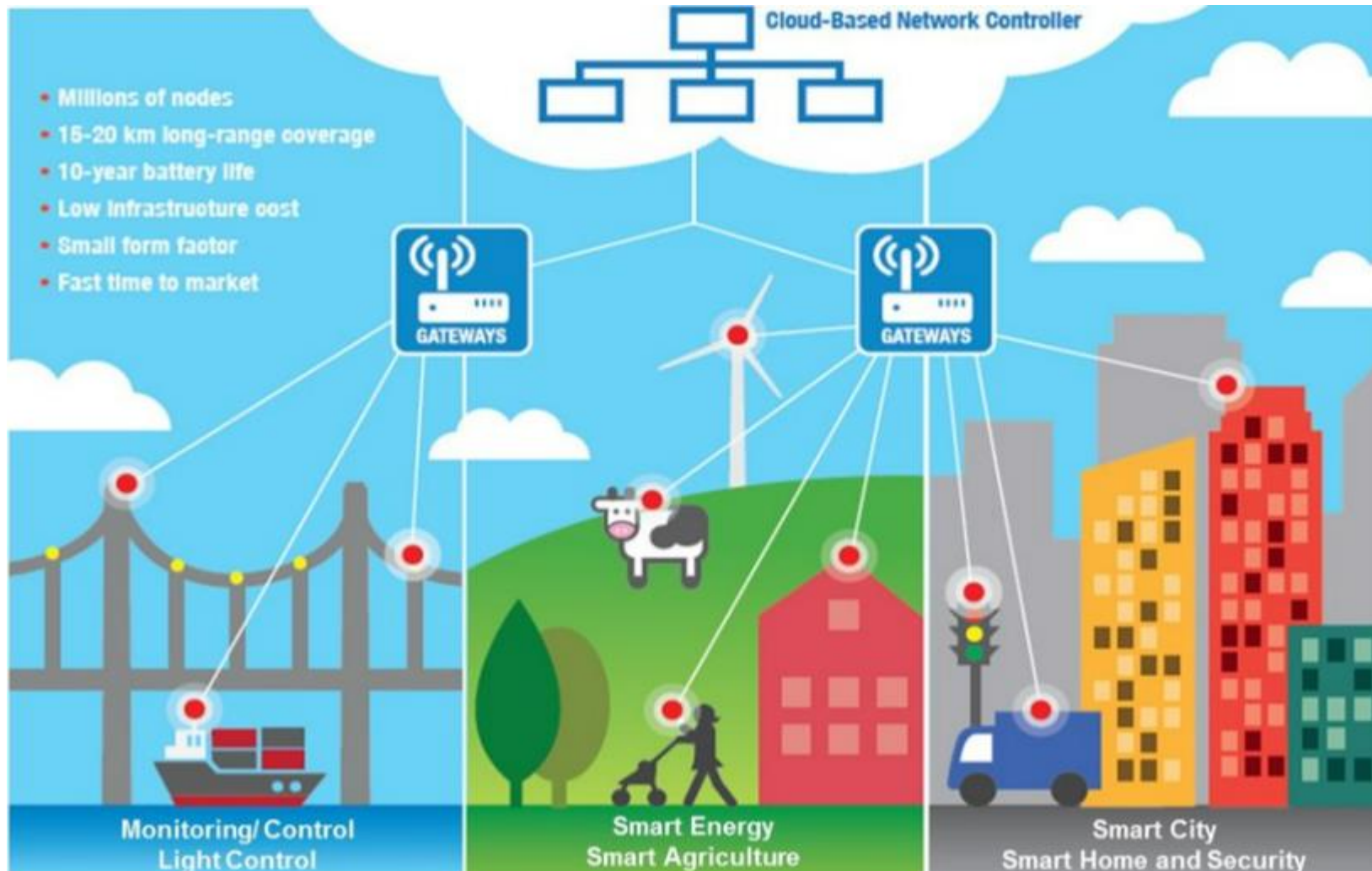
Teknologi LPWAN

	SIGFOX	LoRaWAN	NB-IoT
Modulation	BPSK	CSS	QPSK
Frequency	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia)	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia)	Licensed LTE frequency bands
Bandwidth	100 Hz	250 kHz and 125 kHz	200 kHz
Maximum data rate	100 bps	50 kbps	200 kbps
Bidirectional	Limited / Half-duplex	Yes / Half-duplex	Yes / Half-duplex
Maximum messages/day	140 (UL), 4 (DL)	Unlimited	Unlimited
Maximum payload length	12 bytes (UL), 8 bytes (DL)	243 bytes	1600 bytes
Range	10 km (urban), 40 km (rural)	5 km (urban), 20 km (rural)	1 km (urban), 10 km (rural)
Interference immunity	Very high	Very high	Low
Authentication & encryption	Not supported	Yes (AES 128b)	Yes (LTE encryption)
Adaptive data rate	No	Yes	No
Handover	End-devices do not join a single base station	End-devices do not join a single base station	End-devices join a single base station
Localization	Yes (RSSI)	Yes (TDOA)	No (under specification)
Allow private network	No	Yes	No
Standardization	Collaborating with ETSI	LoRa Alliance	3GPP

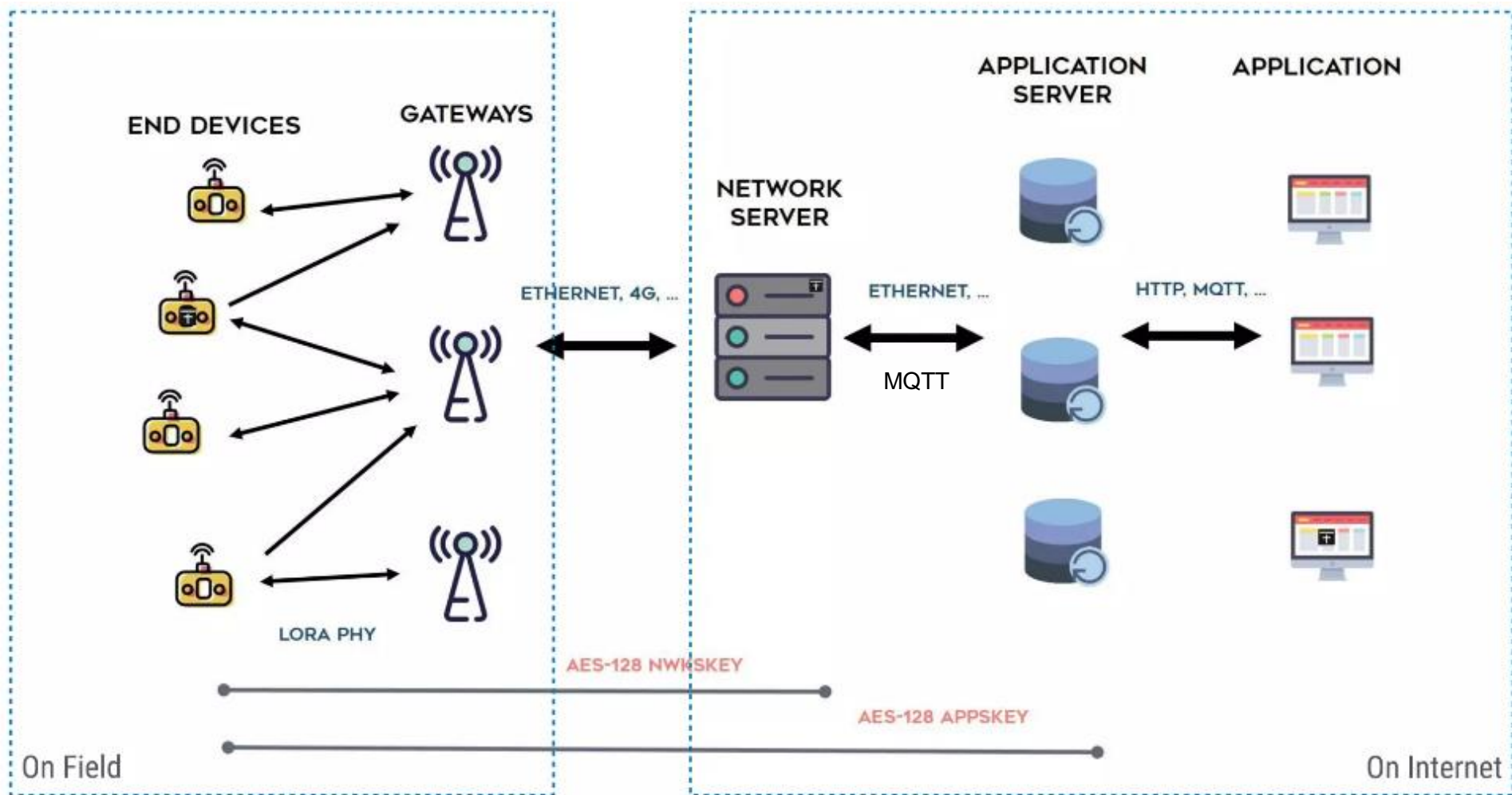
Perbandingan spesifikasi teknis LPWAN



Target market LoRa: Ideal utk IoT

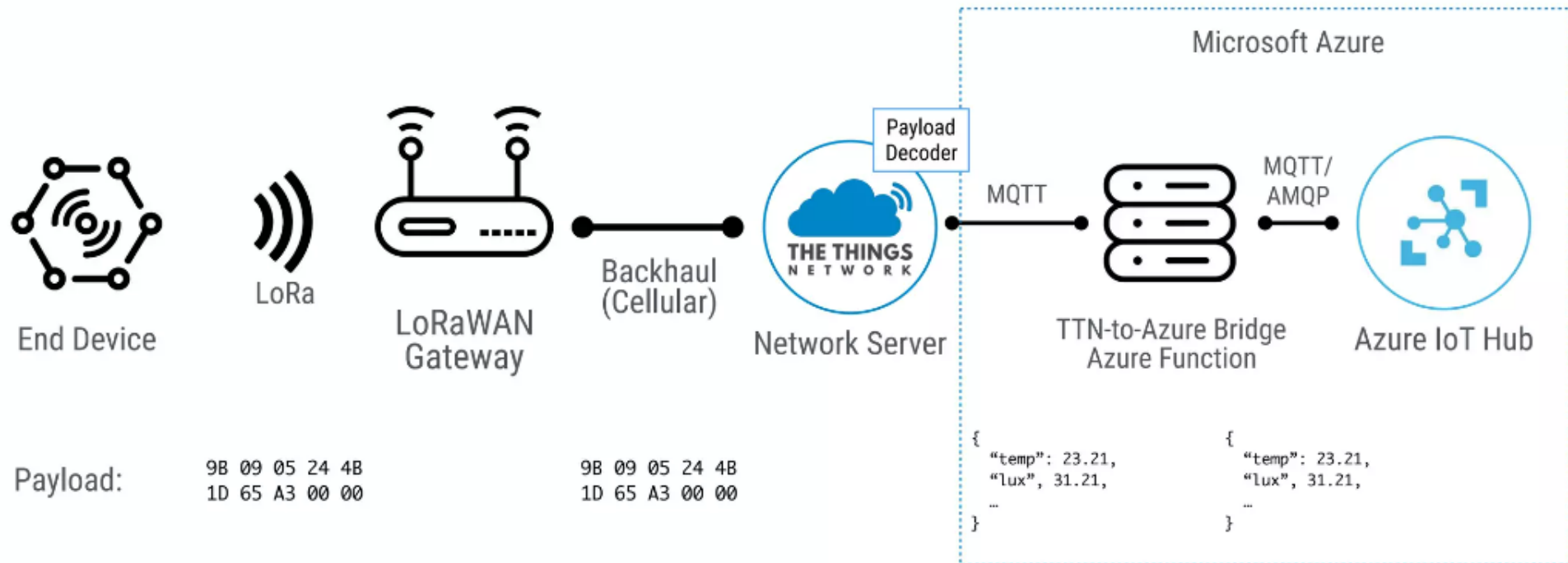


Entitas LoRaWAN



Source: <http://www.fruqalprototype.com/technologie-lora-reseau-lorawan/>

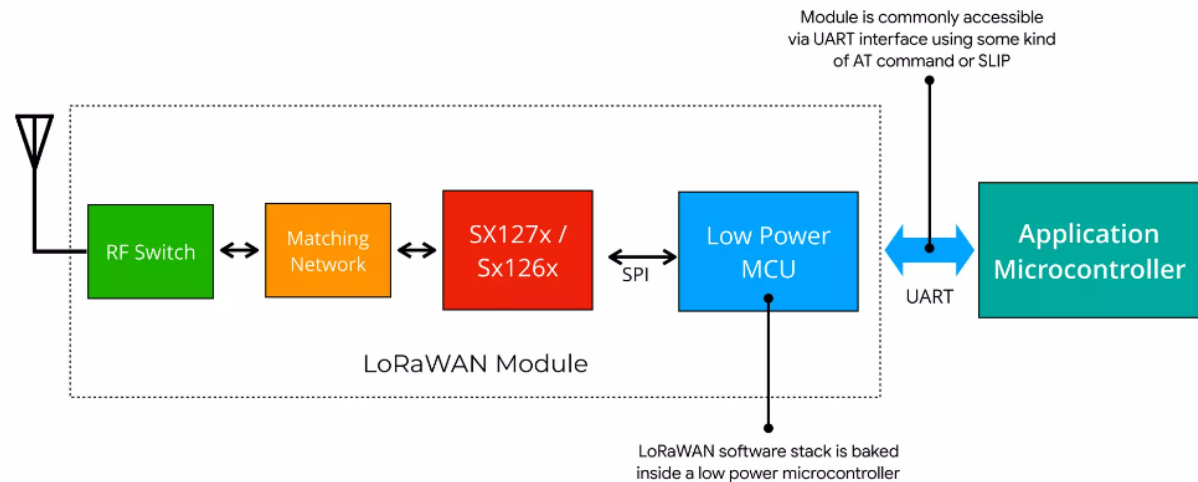
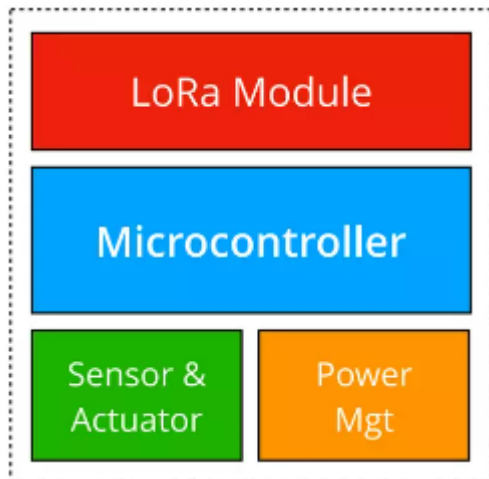
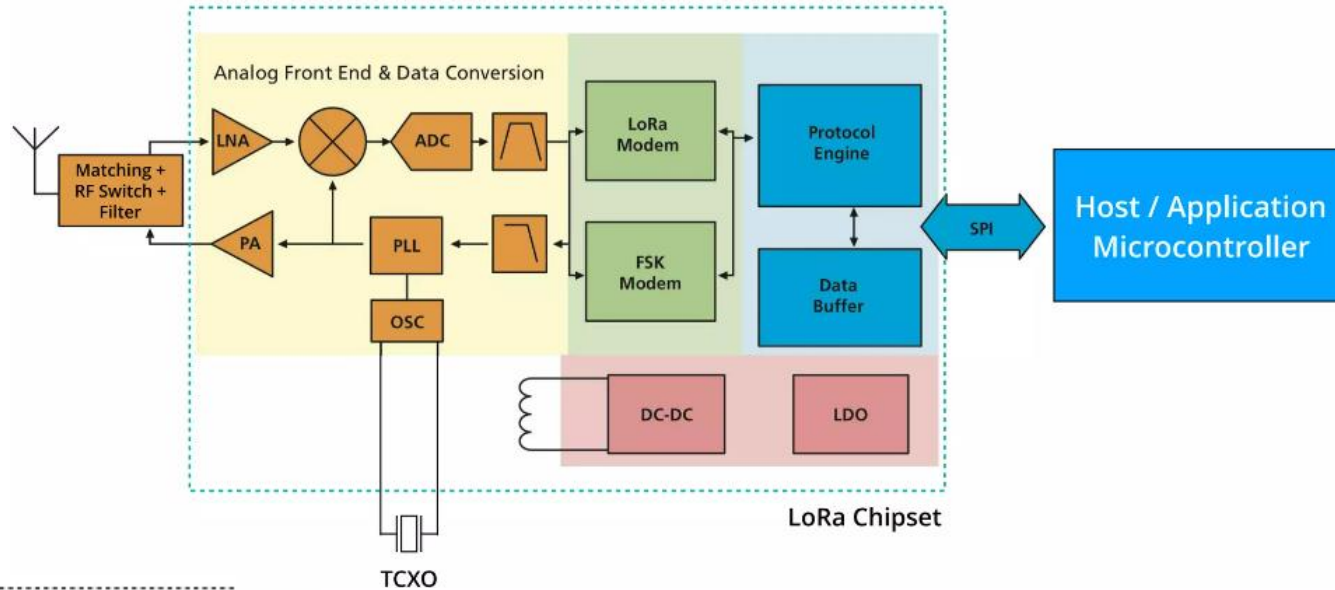
Entitas LoRaWAN



LoRaWAN: End Device

- LoRa client device: disebut **mote / node**
- Berkomunikasi dengan **gateway**
 - Tidak pernah berkomunikasi dengan mote / node lain
- Mempunyai globally unique identifier yang disebut **DevEUI**
 - Dengan format IEEE EUI64 (64 bit)
- Mempunyai network unique identifier yang disebut **DevAddr**
 - Network unique 32 bit

LoRaWAN: End Device



LoRaWAN: End Device

Size: 55mm x 20mm x 3.5mm

Operating temperature:
-40 to 85 degrees celsius

ESP32 Dual Core
Microcontroller and
WiFi/Bluetooth 4.2
radio

3V3 Ultra-Low
-Noise switching
regulator

LoRa transceiver

32Mbit flash memory

WS2812 RGB
multi-colour
LED



External LoRa antenna
connector

Reset switch

RF switch

U.FL connector

Internal WiFi and
Bluetooth Antenna

LoRaWAN: End Device

To make life easier, just use Dev Board with LoRa/LoRaWAN



Pycom LoPy



STM32L0 Discovery kit LoRa



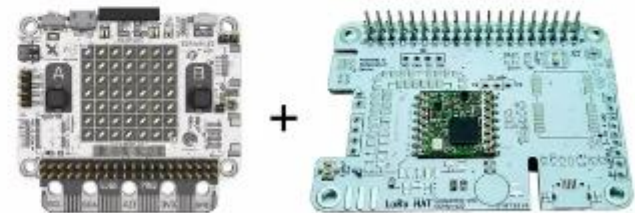
Arduino MKR WAN 1300



Adafruit Feather M0 with RFM95



Sodaq ONE



DycodeX ESpectro32 + LoRa Backpack

LoRaWAN: Kelas Perangkat

Class A (lowest power)	ALOHA based, with comms always initiated by end device. After transmit, device listens for replies or network control for a short time period.
Class B (deterministic downlink)	Supports Class A transmissions, plus periodically listens for network messages on a schedule. Still suitable for battery use, but less efficient than Class A.
Class C (lowest latency)	Supports Class A transmissions, plus actively listens for network messages. Not suitable for battery use.

LoRaWAN: Gateway

- Sisi infrastruktur radio
- Disebut juga **concentrator** atau **base-station**
- Berkomunikasi dengan end device melalui **LoRaWAN**
- Berkomunikasi dengan network server melalui **TCP/IP**
- Dapat berjalan bersama-sama pada multi protocol di base-station
- Menjalankan minimal firmware atau OS, dan software packet forwarding

LoRaWAN: Gateway



LoRaWAN: Network Server (NS)

- **Network Server** men-terminasi LoRAWAN MAC Layer untuk end device yang terhubung ke jaringan
- Sebagai **pusat** dari star topology
- **Network Server** melakukan:
 - Gateway mana yang akan berkomunikasi ke end device
 - Data rate yang akan digunakan oleh end device

LoRaWAN: Network Server (NS)



THE THINGS
N E T W O R K



LORION



LoRaWAN: Join Server (JS)

- Server di sisi internet (network server)
- Proses **join request** dari end device
- End device tidak dapat digunakan tanpa melakukan join network
- Dikombinasikan dengan Network Server

LoRaWAN: Uplink Message

- Komunikasi dari end device ke network server atau aplikasi
- Diterima melalui satu atau lebih gateway
- Uplink message diterima lebih dari satu gateway, kemudian di-deplikasi oleh Network Server

LoRaWAN: Downlink Message

- Komunikasi dari network server atau aplikasi melalui gateway ke single device atau group end device
- Network Server memutuskan gateway mana yang terbaik untuk mengirim downlink message ke device tertentu

LoRaWAN: Aplikasi

- **Application layer code** berjalan di end device
- Application code berjalan juga di network server
- Sebagian besar end device hanya menjalankan satu aplikasi
- Diidentifikasi dengan mendaftarkan nilai IEEE EUI64 (AppEUI)
- “**Application**” berjalan di Network Server
 - Menyediakan manajemen device
 - Merutekan data ke aplikasi eksternal

LoRaWAN: Enkripsi

- Semua data payload dienkripsi
 - Tidak ada kemungkinan attacker untuk membaca payload
 - Tidak ada kemungkinan network operator untuk membaca payload dan mempunyai data integrity
 - Tidak ada kemungkinan untuk meng-intersep dan me-replay data
- MAC command diproteksi
 - Tidak ada kemungkinan attacker untuk membaca metadata

LoRaWAN: pre-joined Devices (ABP)

- ABP: Authentication By Personalisation
- End device harus memiliki 2 symmetric session key
- Device menggunakan kunci AES 128-bit
- Network Session Key (**NwkSKey**)
 - Digunakan oleh network operator
 - Melindungi network metadata
- Application Session Key (**AppSKey**)
 - Digunakan oleh application operator
 - Dipakai oleh semua end device yang menggunakan aplikasi

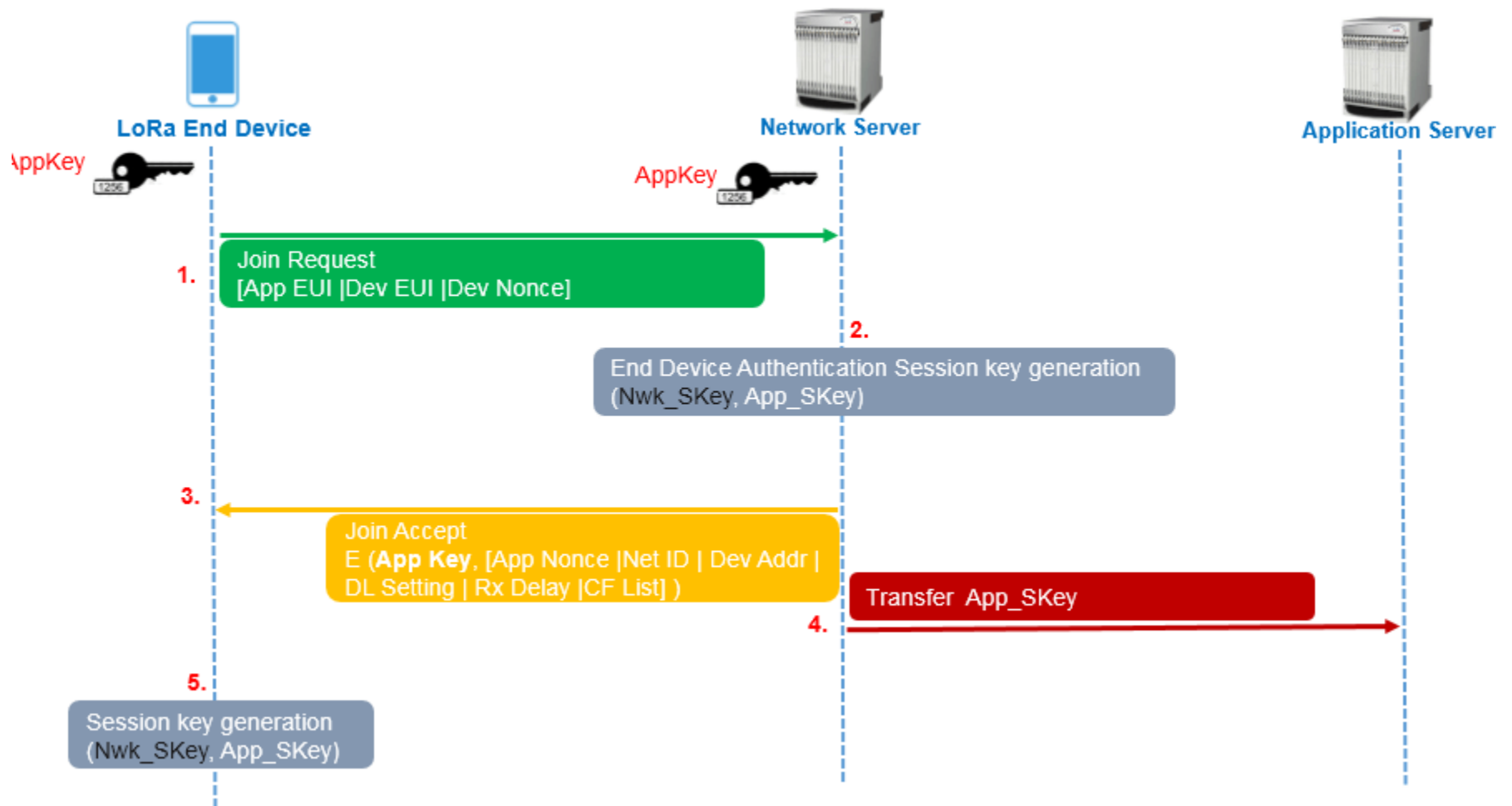
LoRaWAN: Over the Air Activation (OTAA)

- End device harus memiliki 2 symmetric key
- Network Session Key (**NwkSKey**)
- Application Key (**AppKey**)
 - Berbeda dengan **AppSKey**
 - Unik ke setiap End Device
- Device mengirim **DevEUI, AppEUI, AppKey**
- Network mengirim data menggunakan **AppSKey** dan **NwkSKey** (kemudian memproses sbg pre-joined device)

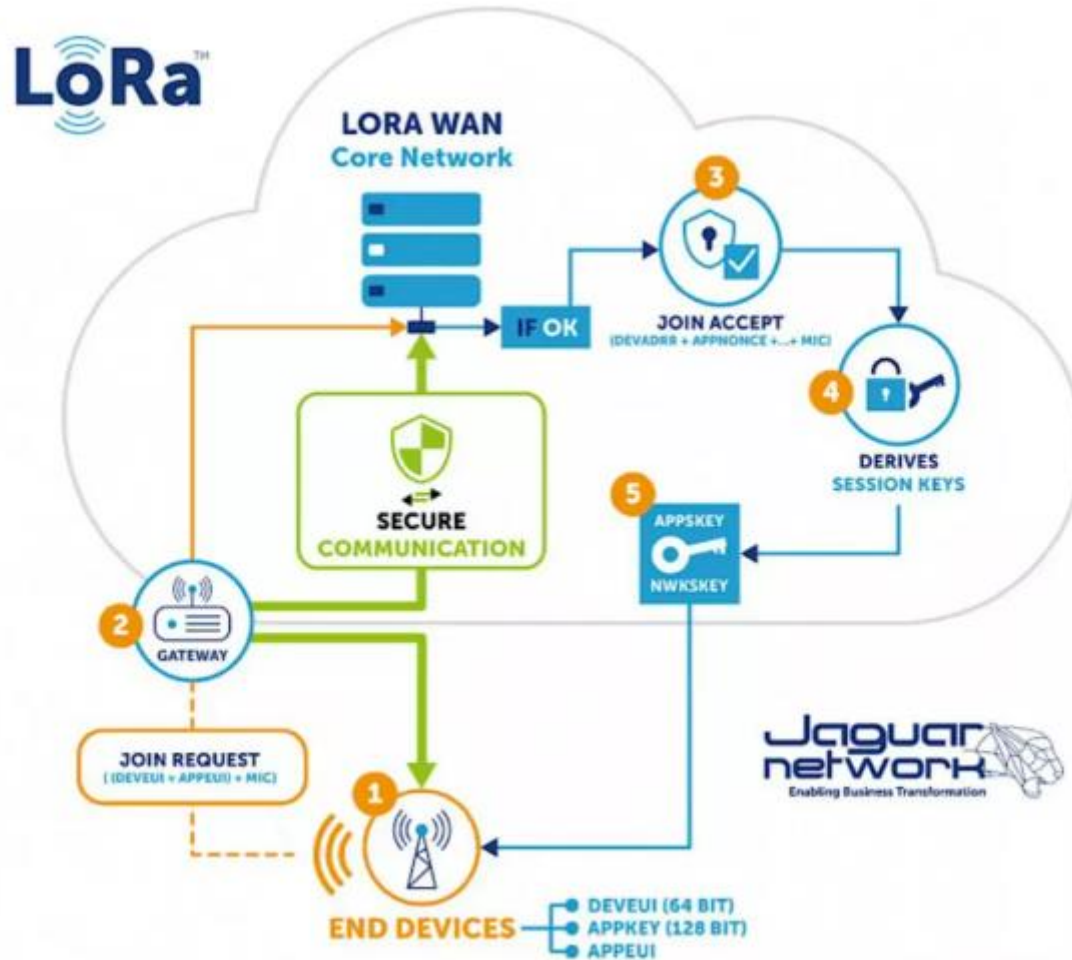
LoRaWAN: OTA Join Process

- **LoRa device** mengirim **JOIN_REQUEST** (signed dengan AppKey).
 - Join request terdiri dari informasi: AppEUI, DevEUI, DevNonce
 - DevNonce adalah bilangan yang dihasilkan secara random
- **Network Server** menerima **JOIN_REQUEST** dan menghitung AppSKey dan NwkSKey berdasarkan: AppKey, AppNonce, NetID, DevNonce
 - AppNonce adalah bilangan yang dihasilkan secara random
- Device menerima **JOIN_ACCEPT** (dienkripsi dengan AppKey).
 - JOIN_ACCEPT berisi informasi: AppNonce, NetID, DevAddr, RFU, RxDely, CFList
- Network Server dan Lora device memiliki informasi kunci yang sama dan Lora Device akan mendapatkan NwkSKey dan AppSKey

LoRaWAN: OTA Join Process



LoRaWAN: OTA Join Process



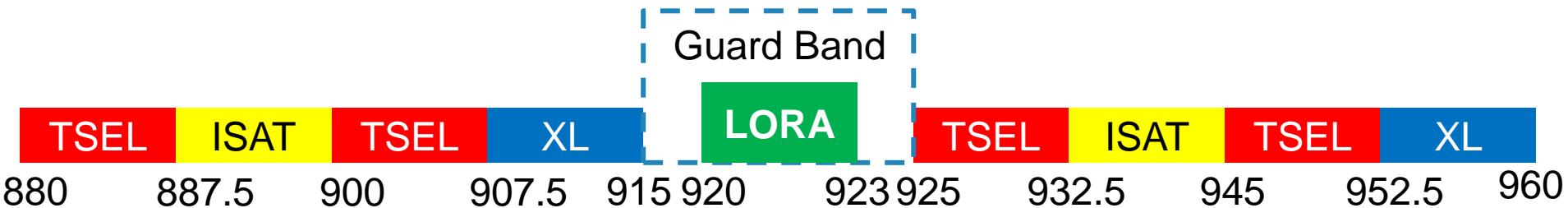
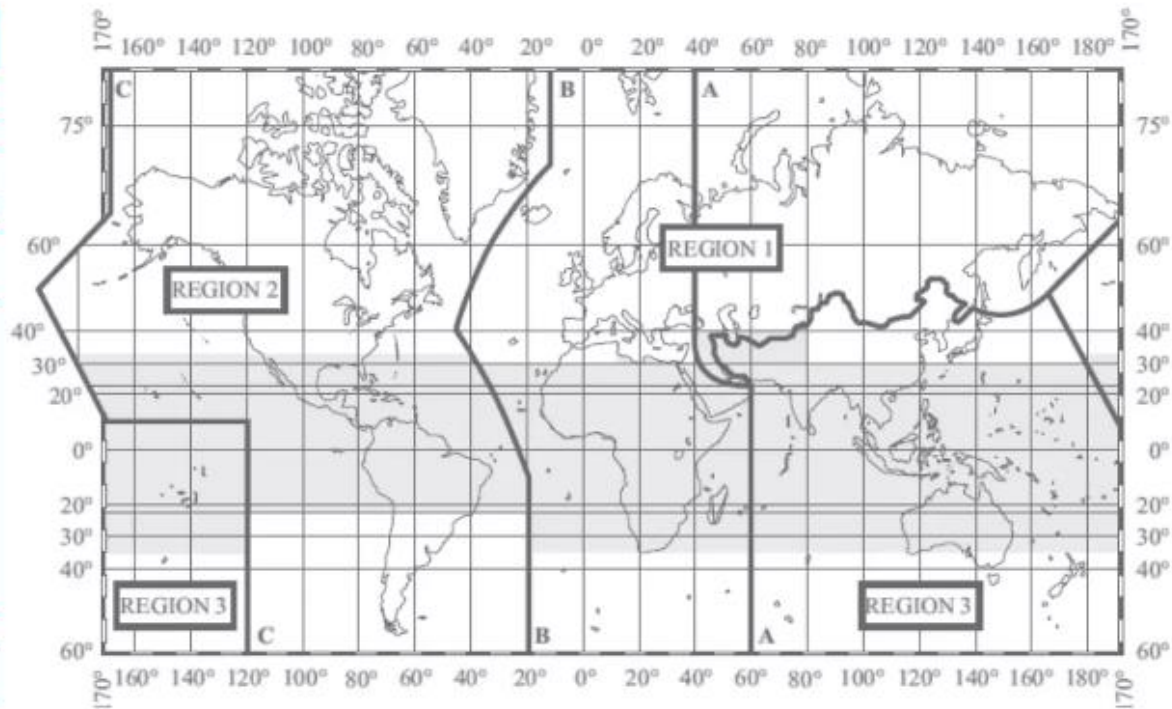
Parameter LoRa

LoRa physical layer consists of many parameters which can be configured into **6720 different settings!**

Setting	Values	Definition	Effects
Bandwidth	125, ..., 500 kHz	Width of spectrum occupied by chirp	A higher bandwidth is required for transmitting data at high rates (1 kHz = 1 kcps). However, increasing this parameter decreases the communication range and sensitivity.
Spreading Factor	$2^6, \dots, 2^{12}$ chips/symbol	Number of bits encoded per symbol. Symbol is RF state representing some quantity of information. SF12 means 2^{12} chips/symbol, 12 bits of data	A higher spreading factor (<i>SF</i>) increases the communication range, radio sensitivity, and the signal-to-noise ratio (SNR). However, energy consumption consequently increases.
Coding Rate	1, ..., 4 or 4/5, ..., 4/8	Proportion of transmitted bits that carries actual data, as opposed to error correction bits. $CR1 \rightarrow 4/(4+1) = 4/5$	Bigger coding rates increase the protection against decoding errors and interference bursts at the expense of longer packets, longer air time, and higher power consumption.
Transmission Power	-4, ..., 20 dBm	Transmission power can be adjusted from -4 to 20 dBm, in 1 dB steps. Because of hardware implementation limits, the range is often limited to 2 to 20 dBm.	The signal-to-noise ratio is increased by increasing the transmission power at the cost of energy expenditure.
Carrier Frequency	137, ..., 1020 MHz	CF represents the central transmission frequency used in a band, can be programmed between 137 MHz to 1020 MHz, in steps of 61 Hz.	Lower frequency enables to achieve higher communication ranges for the same transmission power. However, selected CF needs to comply with country's regulation.

LoRaWAN: Frequency Band

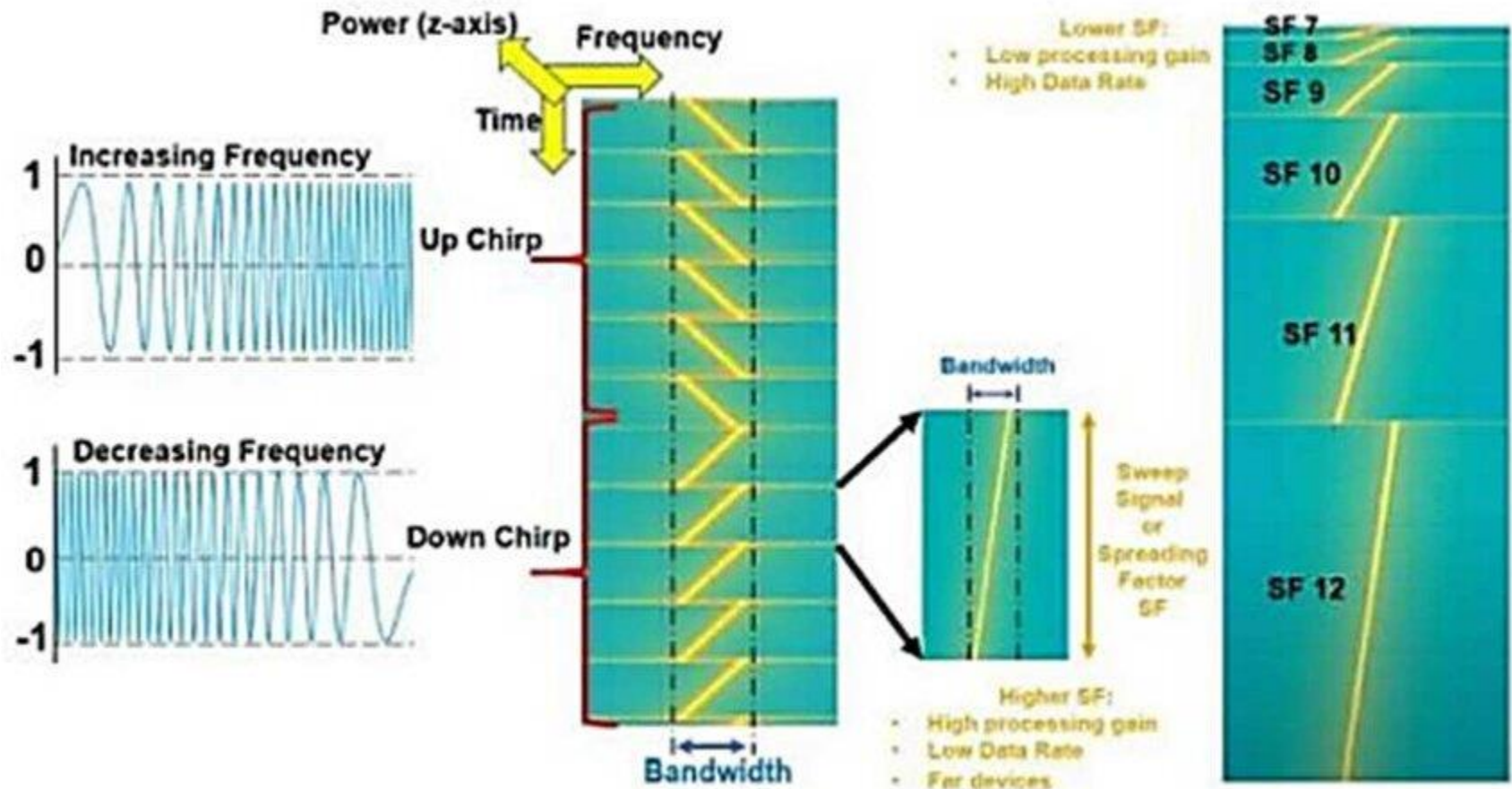
Countries	Frequency band review	Max. output power
EU	868 MHz	14 dBm
USA	915 MHz	20 dBm
Korea	900 MHz	14 dBm
Japan	920 MHz	
Malaysia	862 to 875 MHz	
Philippines	868 MHz	
Vietnam	920 to 925 MHz	
India	865 to 867 MHz	
Singapore	922 MHz	
Thailand	920 to 925 MHz	
Indonesia	920 to 923 MHz *	
ANZ	915 to 928 MHz	
Taiwan	920 to 925 MHz	20 dBm
China	470 to 510 MHz	17 dBm



LoRaWAN: Chirp Spread Spectrum

- 3 bandwidth yang digunakan:
 - 125 KHz
 - 250 KHz
 - 500 KHz
- 6 Spreading Factor (SF) yang digunakan:
 - SF7 – SF12

LoRaWAN: Chirp Spread Spectrum

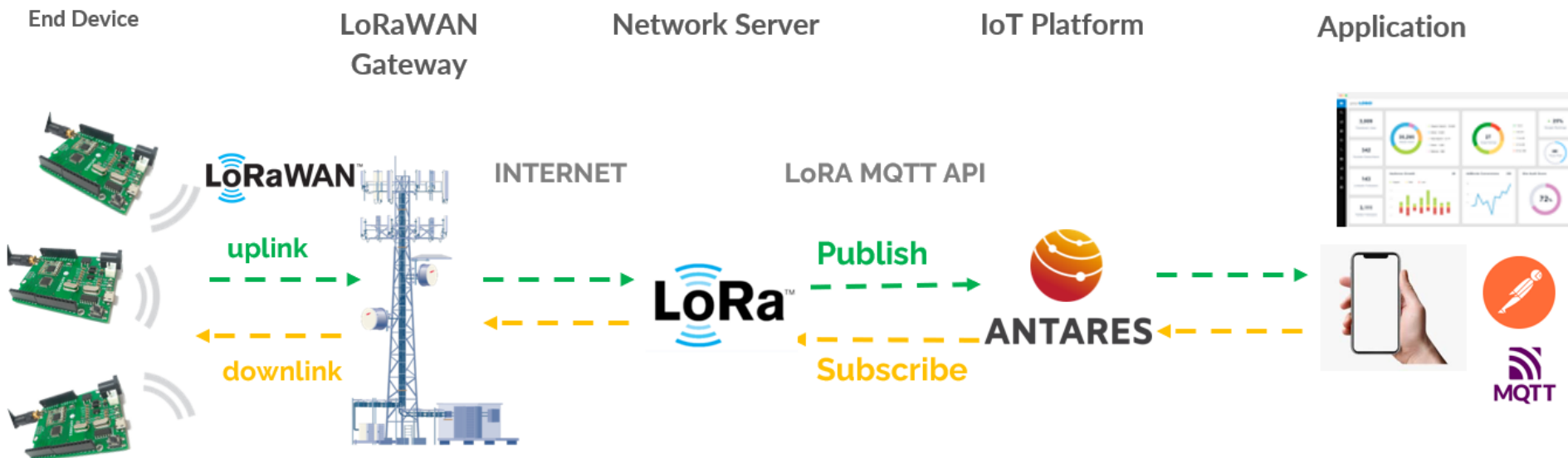


LoRaWAN: Data rate

- Data rate = bandwidth * spreading factor
- Paling rendah = SF 12 * 125 KHz = 250 bps
- Paling tinggi = SF 7 * 500 KHz = 21.9 kbps

PT Telkom: LoRaWAN

Network Configuration



LoRaWAN Telkom Parameter

Channel Plan AS923-2

Uplink Channel

(SF7-12 BW125kHz)

- 921.2 MHz
- **921.4 MHz – Join ch**
- **921.6 MHz – Join ch**
- 921.8 MHz
- 922.0 MHz
- 922.2 MHz
- 922.4 MHz

Downlink Channel

921.4 MHz SF10 BW125

*Notes: AS923-2 shifts the plan down 1.8MHz from AS923 (based on LoRa Alliance standard)

Support LoRaWAN Class
A & C

Support Activation Mode
ABP & OTAA

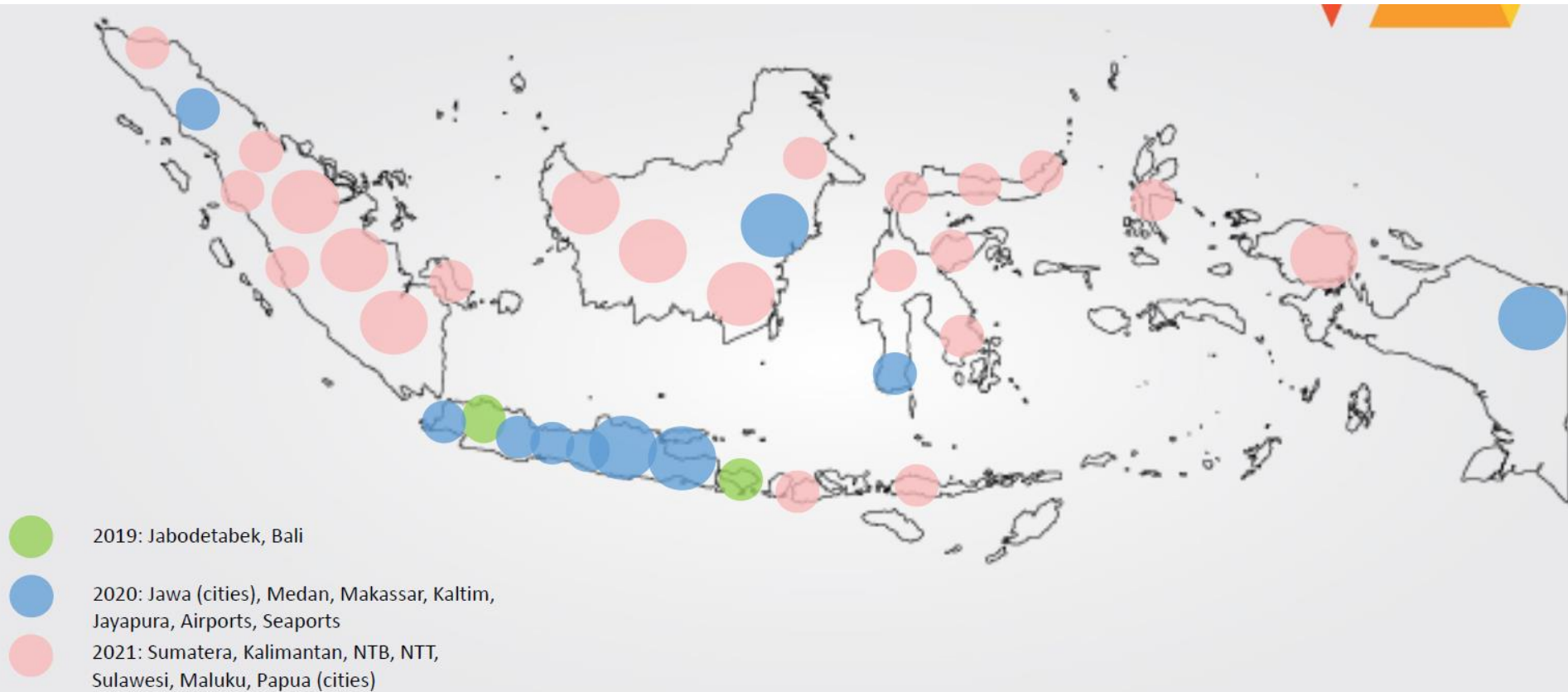
Register Your LoRa Device at



ANTARES

Collect your data using RESTFUL API / MQTT <https://antares.id/>

Telkom LoRaWAN Coverage



Contoh Aplikasi: Dycodex

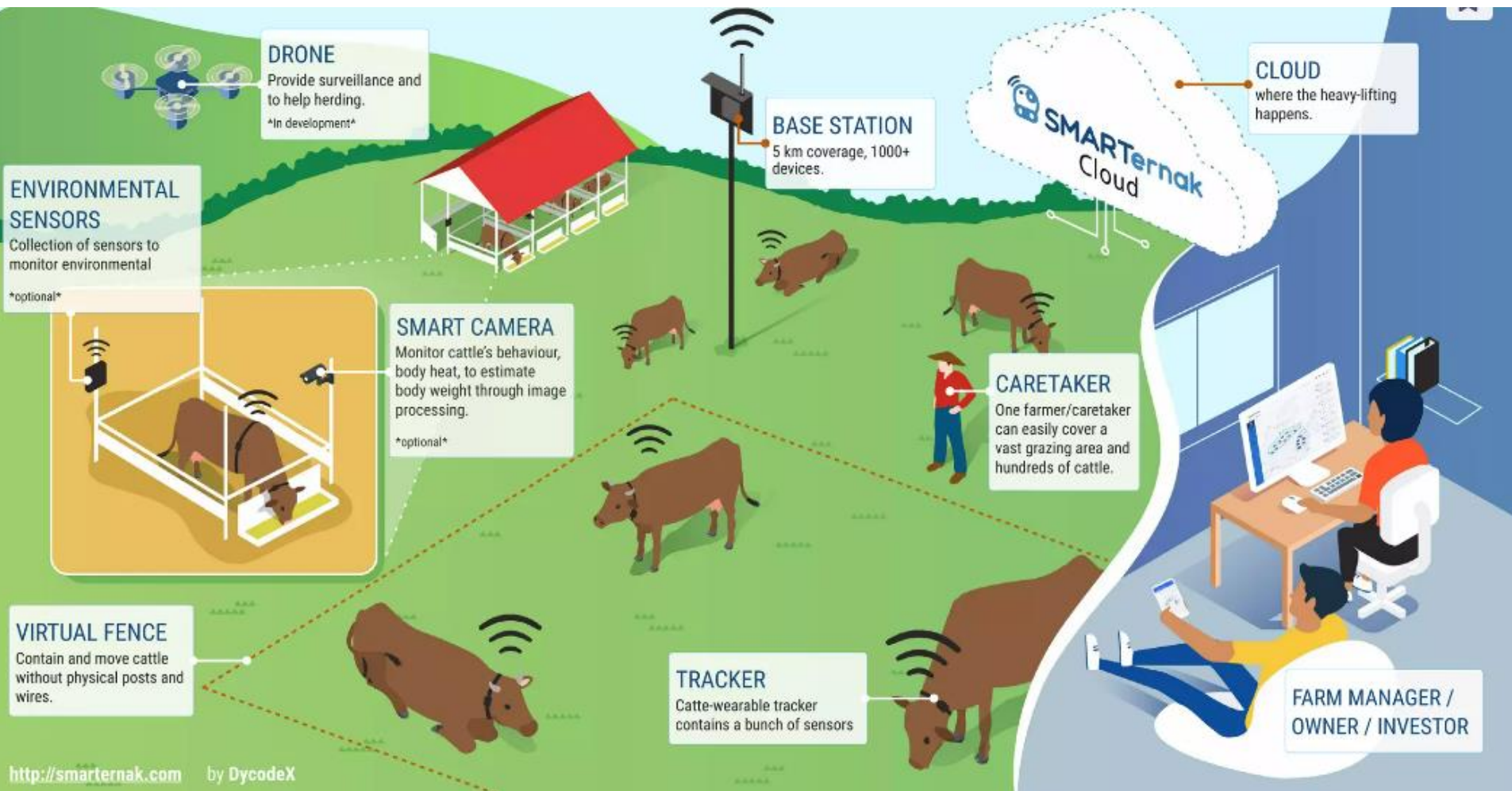


**Internet of Things & Artificial Intelligence-powered
Cattle-Farm Assistant Platform**

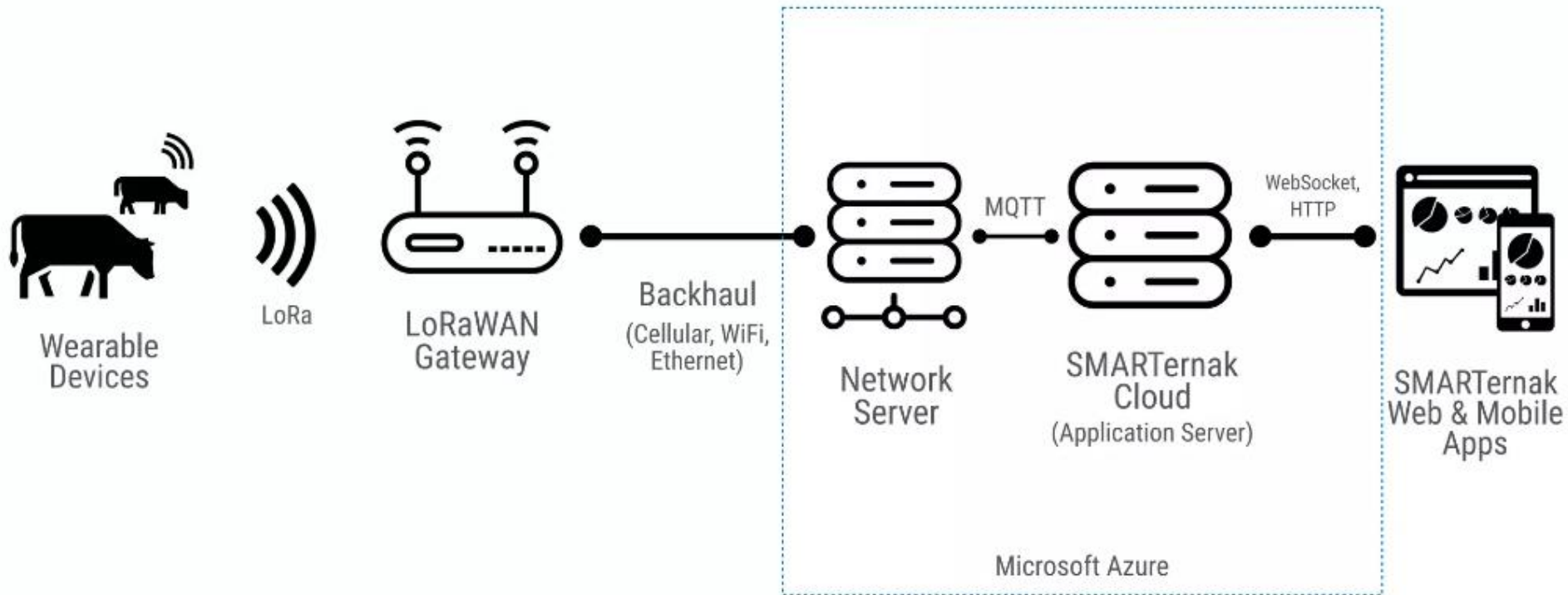
* "Ternak" in SMARTernak means "cattle" in Bahasa Indonesia



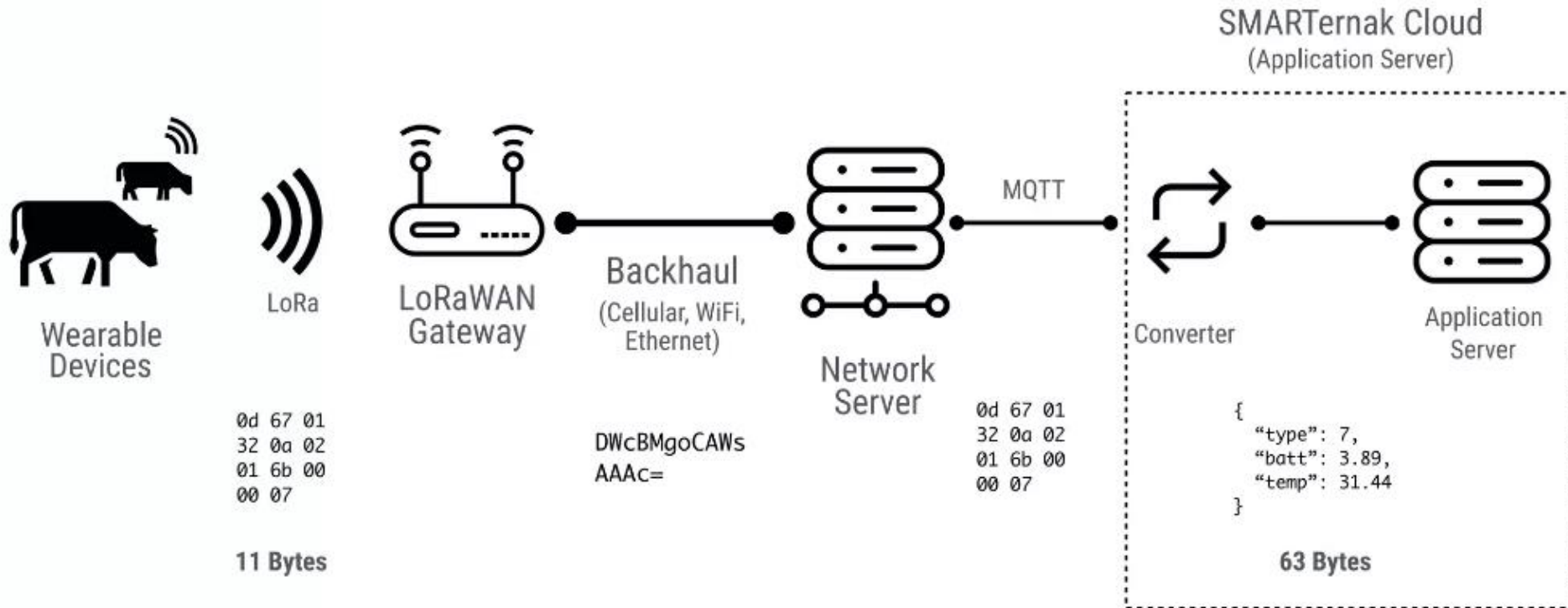
SMARTernak: Cara Kerja



SMARTernak Architecture with LoRa/LoRaWAN



SMARTernak Architecture: Data Perspective



Cattle-wearable Device



Dual IoT Connectivity

Short Range: 1 km WiFi, Bluetooth v4.2, BLE
Mesh-supported. High speed

Long Range: LoRa/LoRaWAN or NB-IoT,
for 5-10km coverage area

Powerhouse

Low Power, Dual Core Microcontroller

Actuators

Audio Alert/Speaker
Color LED

Packed with Sensors

GPS / GNSS
Accelerometer, Gyroscope
Body Temperature
Ambient Temperature & Humidity
Barometric Pressure
Ambient Light
MEMS Microphone
Device Removal Detector



Smart Energy

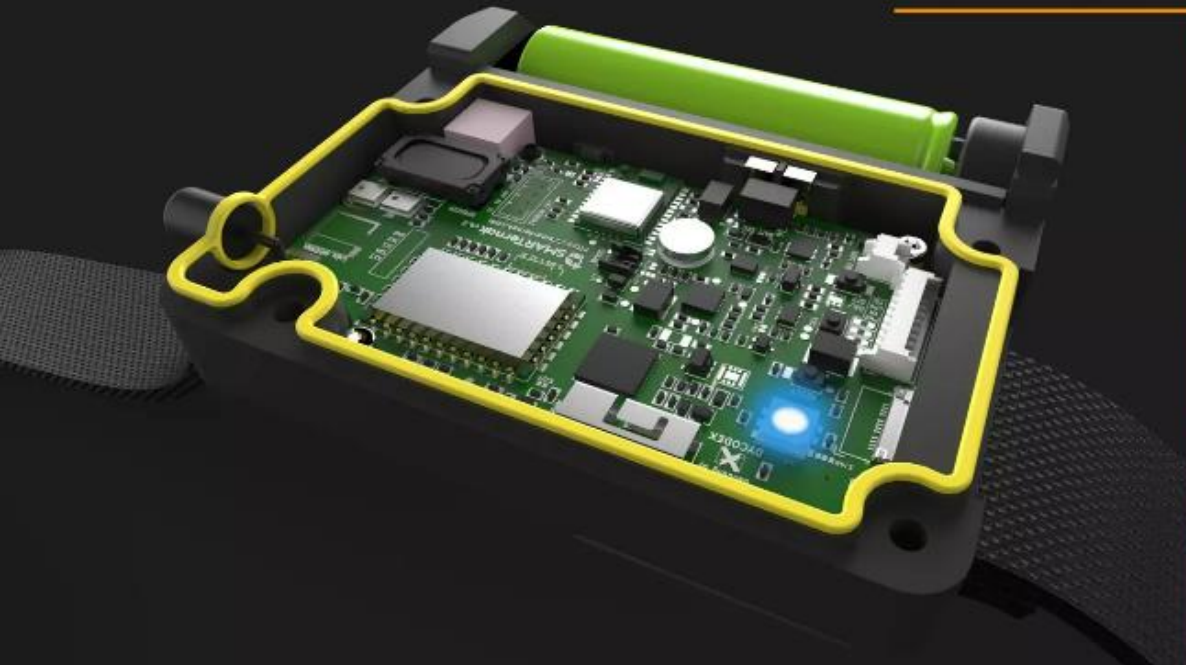
Battery Gauge
Solar Energy Harvesting
Smart Switching Between
Main & Backup Battery
Fast Charging from USB Type-C
Firmware-optimised
power consumption

Device Internals

In-House

Electronics board is 100% designed and assembled in-house, by 100% Indonesian

LoRaWAN Module



16
15
14
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6



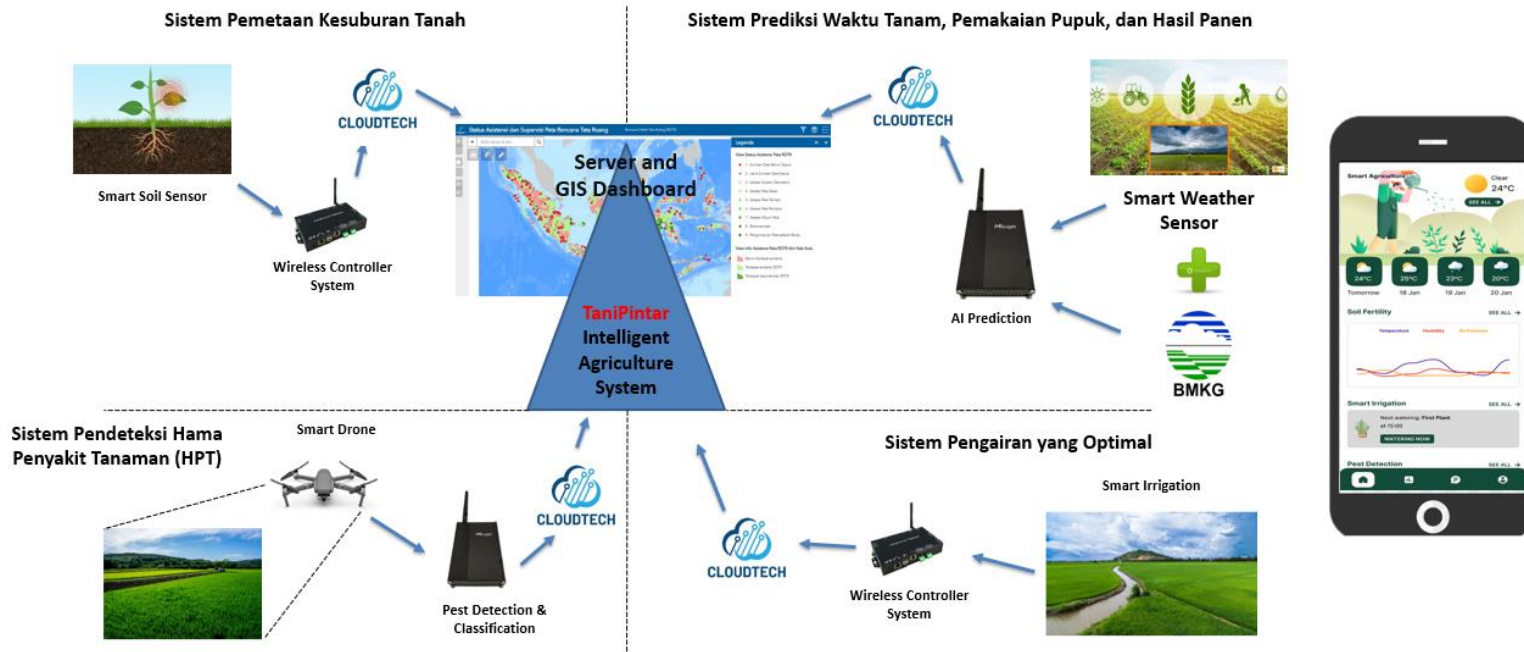
SMARTernak real-world deployment, uses LoRa/LoRaWAN



...and we successfully achieved real-world 5km coverage!



Contoh Aplikasi: Smart Agriculture



Platform Portable taniJOSS

