Introduction

Pourquoi faire une these ?

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Outline

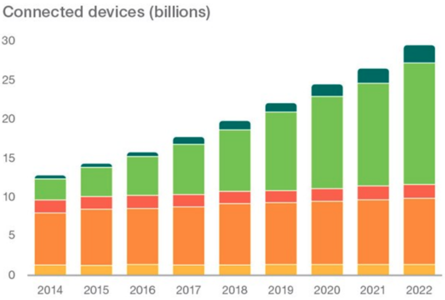
1. Introduction
   1. IoT Devices
   2. IoT Applications
   3. IoT Wireless Communications

Outline

1. Introduction

Massive IoT devices

IoT devices are useless without a good communication capability



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

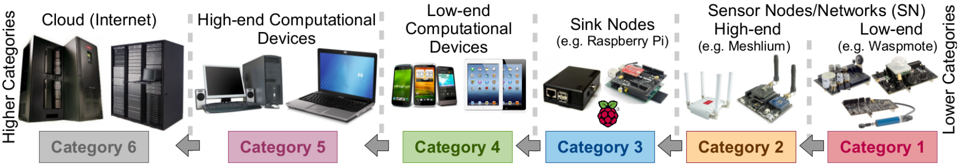


Figure 1. IoT devices **perera_mosden_2013**.

Outline

Applications diversification

Each application has its own communication requirements

Challenges/Applications	Grids	EHealth	Transport	Cities	**Building**
Resources constraints	✗	✓	✗	-	✗
Mobility	✗	-	✓	✓	✗
Heterogeneity	-	-	-	✓	✗
Scalability	✓	-	✓	✓	-
QoS constraints	-	-	✓	✓	✓
Data management	-	✗	✓	✓	-
Lack of Standardization	-	-	-	-	✓
Amount of attacks	✗	✗	✓	✓	✓
Safety	-	✓	✓	-	✓

Table 1. Main IoT challenges **kouicem_internet_2018** [1]

Figure 2. IoT Applications.

IoT platforms

IoT platforms is a chain of communication process

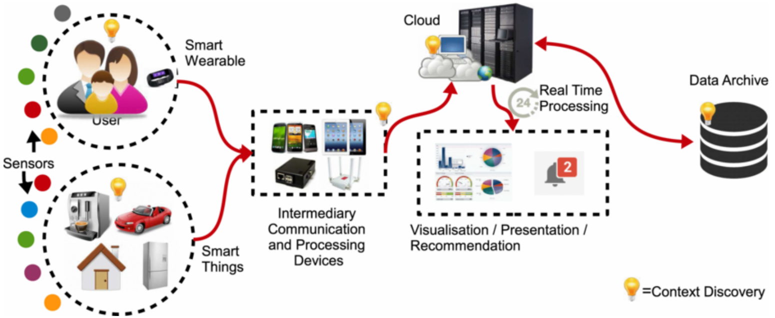


Figure 3. IoT platform.

Figure 4. IoT challenges.

Applications diversification

Requirements

Use Case	Packet rate [pkt/day]	Min success rate [Ps,min]	Payload Size [Byte]
Wearables	10	90	
Smoke Detectors	2	90	
Smart Grid	10	90	10-20
White Goods	3	90	
Waste Management	24	90	
VIP/Pet Tracking	48	90	
Smart Bicycle	192	90	
Animal Tracking	100	90	
Environmental Monitoring	5	90	
Asset Tracking	100	90	50
Smart Parking	60	90	
Alarms/Actuators	5	90	
Home Automation	5	90	
Machinery Control	100	90	
Water/Gas Metering	8	90	
Environmental Data Collection	24	90	
Medical Assisted Living	8	90	
Micro-generation	2	90	
Safety Monitoring	2	90	100-200
Propane Tank Monitoring	2	90	
Stationary Monitoring	4	90	
Urban Lighting	5	90	
Vending Machines Payment	100	90	
Vending Machines General	1	90	1K

Table 2. Application requirements for the use cases of interest [2] [1] [3]

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1. LoRa

IoT wireless communication

Wireless communication performance need to be evaluated to match applications requirements

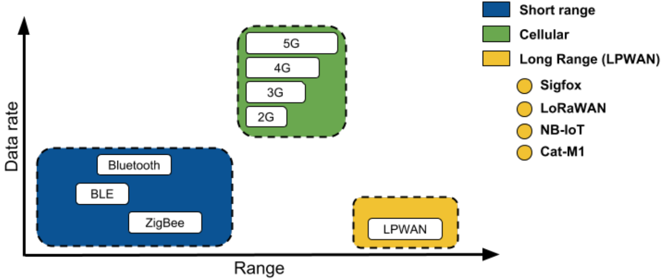

Figure 5. Short range, Cellular and Long range networks.

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1. LoRa

Wireless communication

Exp: LPWAN in a new technology that satisfy IoT applications requirements

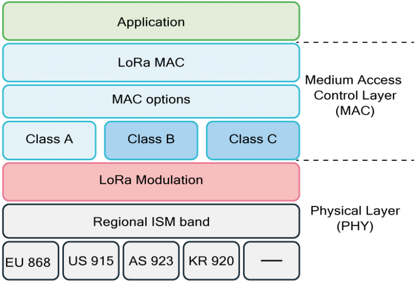

Figure 6. LoRa and LoRaWan stack.

LoRa parameters selection

How to select the optimal configuration

- Parameters
  - Bandwidth (BW)
  - Spreading Factor (SF)
  - Coding Rate (CR)
  - Transmission Power (P^{tx})
  - Payload size (PS)
  - Signal Noise Rate (SNR) [-7.5,-20dBm]

- Metrics
  - Data Rate (DR)
  - Air Time (AT)
  - PS_{max}
  - Received Signal Strength Indication (RSSI) [-30,-120dBm]

Setting	Values	Rewards	Costs
BW	7.8 ➠ $500kHz$	DR	RSSI, Range
SF	2^6 ➠ 2^{12}	RSSI, Range	DR, SNR, PS_{max}, P^{tx}
CR	$4/5$ ➠ $4/8$	SNR	PS_{max}, P^{tx}, AT
P^{tx}	-4 ➠ $20dBm$	SNR	P^{tx}
PS	59 ➠ $230B$	PS	P^{tx}, AT

Table 3. LoRa parameters selection [4]

Multi criteria decision making

Layer	Maximize (Reward)	Minimize (Cost)
Application	Sec security	Service Cost (SC)
Network	Range	Jitter (Jit)
	Packet delivery Ratio (PDR)	Traffic congestion (TC)
	PS	Round-Trip Delay (RTD)
	DR	Packet Error Rate (PER)
		Time Complexity (O_{time})
		Space Complexity (O_{space})
Radio	Mobility (Mob)	Bit Error Rate (BER)
	Symbol Rate (SR)	P^{tx}
	Bit Rate (BR)	Co-channel Interference (CCI)
	Signal-to-Interference Ratio (SIR)	Duty cycle (DC)
	RSSI	Time on Air (ToA)
	Signal-to-interference & noise ratio (SINR)	Path loss (PL)
	SNR	

Table 4. Network selection inputs and classification of parameters **bendaoud_network_2019 chowdhury_survey_2018**

Multi criteria decision making

$$\text{ToA}_{LoRa} = \frac{2^{SF}}{BW}\left((NP+4.25)+\left(SW+\max\left(\left\lceil\frac{8PS-4SF+28+16CRC-20IH}{4(SF-2DE)}\right\rceil(CR+4),0\right)\right)\right)$$

$$\text{ToA}_{\textbf{GFSK}} = \frac{8}{DR}(NP+SW+PL+2CRC) \tag{1}$$

$$\text{RS}_{\textbf{[dBm]}} = -174+10\log_{10} BW + NF + SNR \tag{2}$$

$$\text{PL}_{\textbf{[B]}} = |RSSI| + SNR + P_{TX} + G_{RX} \tag{3}$$

$$\text{SNR}_{\textbf{[dB]}} = 20.log(\frac{S}{N}) \tag{4}$$

$$\text{RSSI}_{\textbf{[dBm]}} = Tx_{power}.\frac{Rayleigh_{power}}{PL} \tag{5}$$

$$\text{SINR}_{\textbf{[dBm]}} = \tag{6}$$

$$\text{BR}_{\textbf{[bps]}} = SF * \frac{\frac{4}{4+CR}}{\frac{2SF}{BW}} \tag{7}$$

$$\text{BER}_{\textbf{[bps]}} = \frac{8}{15}\cdot\frac{1}{16}\cdot\sum k = 216-1^{k}(\frac{16}{k})e^{20.SINR(\frac{1}{k}-1)} \tag{8}$$

$$\text{PER}_{\textbf{[pps]}} = 1-(1-BER)^{n_{bits}} \tag{9}$$

$$\tag{10}$$

Where:

- NP = 8, if LoRa . 5, if GFSK
- SW = 8, if LoRa . 3, if GFSK
- CRC = 0 if downlink packet. 1 if uplink packet
- IH = 0 if header. 1 if no header present
- DE = 1 if data rate optimization. 0 if not
- PS = PHY_Payload bytes
- SF = 7, 8, 9, 10, 11, 12
- BW = bandwidth
- CR = Indicates the Coding Rate

LoRa Frame

Preamble		Sync msg	PHY Header	PHDR-CRC						
Modulation	length	Sync msg	PHY Header	PHDR-CRC	MAC Header					
Modulation	length	Sync msg	PHY Header	PHDR-CRC	MType	RFU	Major			
Modulation	length	Sync msg	PHY Header	PHDR-CRC	MType	RFU	Major	Dev Address		
Modulation	length	Sync msg	PHY Header	PHDR-CRC	MType	RFU	Major	NwkID	NwkAddr	ADR
0	1	2	3	4	5	6	7	8	9	10

PHY Payload									CRC	
MAC Payload								MIC	CRC Type	Polynomial
Frame Header						FPort	**Frame Payload**	MIC	CRC Type	Polynomial
FCtrl				FCnt	FOpts	FPort	**Frame Payload**	MIC	CRC Type	Polynomial
ADRACKReq	ACK	FPending /RFU	FOptsLen	FCnt	FOpts	FPort	**Frame Payload**	MIC	CRC Type	Polynomial
11	12	13	14	15	16	17	18	19	20	21

LoRa Frame

- **Modulation :**
  - Lora: 8 Symbols, 0x34 (Sync Word)
  - FSK: 5 Bytes, 0xC194C1 (Sync Word)

- **Length :**
- **Sync msg :**
- **PHY Header :** It contains:
  - The Payload length (Bytes)
  - **The Code rate**
  - Optional 16bit CRC for payload

- **Phy Header :** CRC It contains CRC of Physical Layer Header
- **MType :** is the message type (uplink or a downlink)
  - whether or not it is a confirmed message (reqst ack)
  - 000 Join Request
  - 001 Join Accept
  - 010 Unconfirmed Data Up
  - 011 Unconfirmed Data Down
  - 100 Confirmed Data Up
  - 101 Confirmed Data Down
  - 110 RFU
  - 111 Proprietary

- **RFU :** Reserved for Future Use
- **Major :** is the LoRaWAN version; currently, only a value of zero is valid
  - 00 LoRaWAN R1
  - 01-11 RFU

- **NwkID :** the short address of the device (Network ID): 31th to 25th
- **NwkAddr :** the short address of the device (Network Address): 24th to 0th
- **ADR :** Network server will change the data rate through appropriate MAC commands
  - 1 To change the data rate
  - 0 No change

- **ADRACKReq :** (Adaptive Data Rate ACK Request): if network doesn't respont in 'ADR-ACK-DELAY' time, end-device switch to next lower data rate.
  - 1 if (ADR-ACK-CNT) >= (ADR-ACK-Limit)
  - 0 otherwise

- **ACK :** (Message Acknowledgement): If end-device is the sender then gateway will send the ACK in next receive window else if gateway is the sender then end-device will send the ACK in next transmission.
  - 1 if confirmed data message
  - 0 otherwise

- **FPending$\downarrow$ /RFU $\uparrow$:** (Only in downlink), if gateway has more data pending to be send then it asks end-device to open another receive window ASAP
  - 1 to ask for more receive windows
  - 0 otherwise

- **FOptsLen :** is the length of the FOpts field in bytes ă 0000 to 1111
- **FCnt :** 2 type of frame counters
  - FCntUp: counter for uplink data frame, MAX-FCNT-GAP
  - FCntDown: counter for downlink data frame, MAX-FCNY-GAP

- **FOpts :** is used to piggyback MAC commands on a data message
- **FPort :** a multiplexing port field
  - 0 the payload contains only MAC commands
  - 1 to 223 Application Specific
  - 224 & 225 RFU

- **FRMPayload :** (Frame Payload) Encrypted (AES, 128 key length) Data
- **MIC :** is a cryptographic message integrity code
  - computed over the fields MHDR, FHDR, FPort and the encrypted FRMPayload.

- **CRC :** (only in uplink),
  - CCITT $x^{16} + x^{12} + x^5 + 1$
  - IBM $x^{16} + x^{15} + x^5 + 1$

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