IoT Planning (LoRAWAN and NB-IoT cases)

FACE-TO-FACE Training Course on

”TECHNICAL ASPECTS OF WIRELESS SOLUTIONS FOR THE INTERNET OF THINGS (IoT)”

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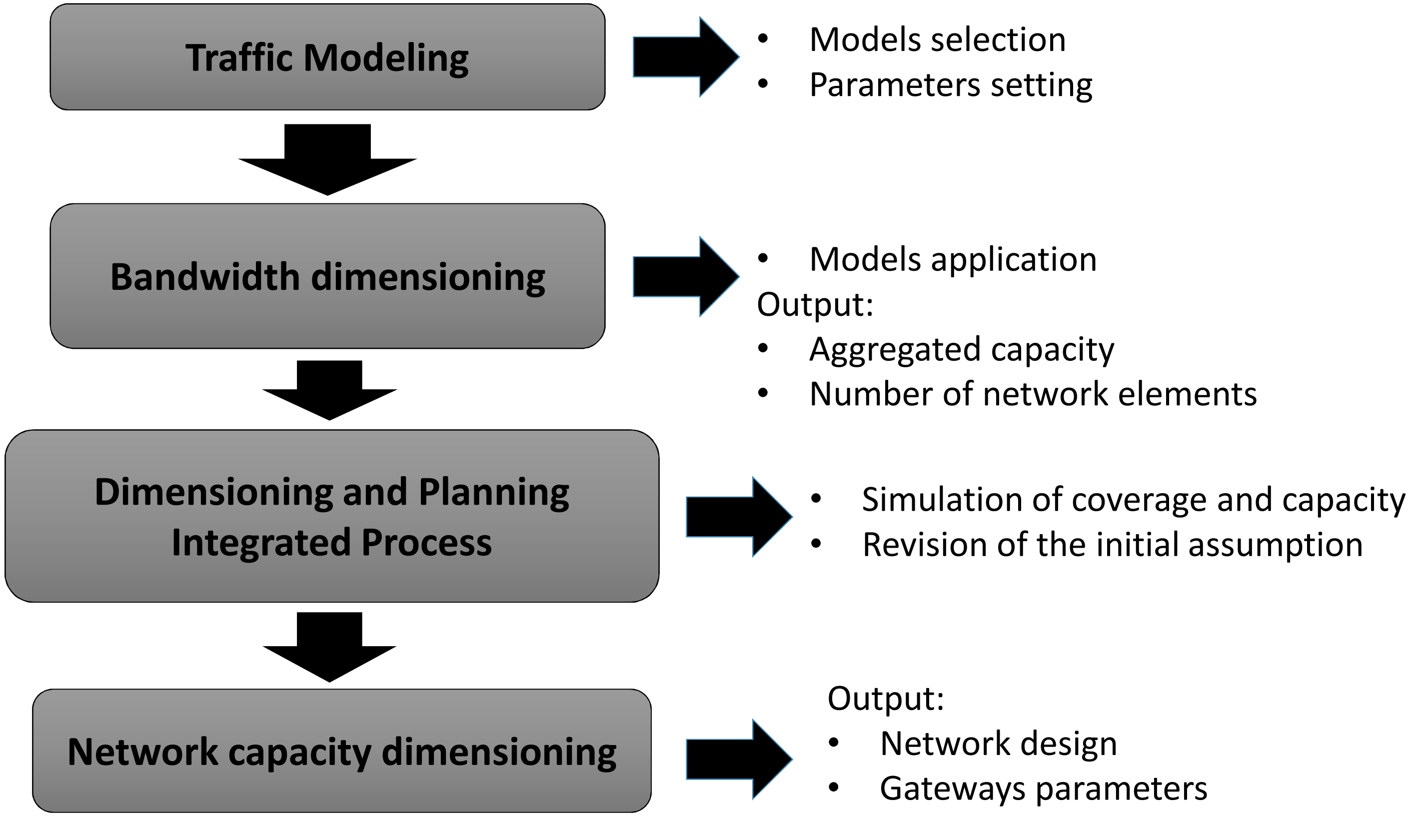
Bangkok, Thailand

Objectives

Present the parameters and methodology for planning an IoT network, starting from the expected services to be proposed.

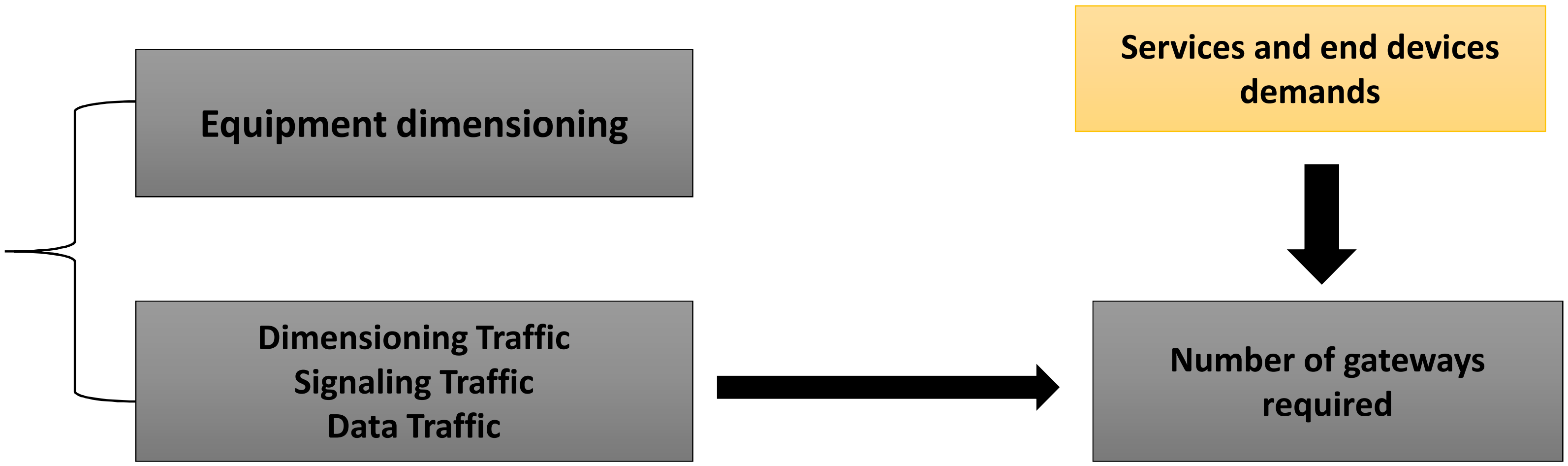
1. Network capacity dimensioning

Dimensioning Steps and Process



Dimensioning Phases

- **Traffic Dimensioning**



Dimensioning Phases

- *Dimensioning preliminary phases*

Phase	Parameters
Initial parameters configuration End devices profiles configuration	• Number of end devices, N • Number of end devices type 1 • … • Number of end devices type k
Traffic at Busy hour	• Packets sizes • Packet arrival rates • Traffic percentage in DL/UL
Signaling Traffic	• Control DL • ACK • …

Traffic dimensioning at BH

- ***Initial parameters (Number of end devices of each type)***

$$N_1 = N_A \; P_1$$
$$N_2 = N_A \; P_2$$
$$\ldots$$
$$N_k = N_A \; P_k$$

Where:

N_i: Number of end devices of type *i*

N_A: Total end devices number

P_i: Type *i* end devices percentage

Traffic dimensioning at BH

- *End devices profile at Busy hour*

Accesses of end devices to the network are for:

- Measurements reporting,
- Alarms,
- Control,
- …

Service characteristics:

- Activity rate per end device,
- Packets sizes.

➔ **Traffic at busy hour:**

$$\rho^{S}_{BH\text{-}DL/UL} = (T_{session}\ N_{session})$$

Where

$\rho^{S}_{BH\text{-}DL/UL}$: Traffic volume in UL/ DL at Busy hour

$T_{session}$: Data volume transmitted per exchange (i.e., session)

$N_{session}$: Number of exchanges at BH

➔ **Traffic on the DL:**

$$\rho^{S}_{BH\text{-}DL} = (\rho^{S}_{BH\text{-}DL/UL}) \quad \rho_{DL}$$

Where:

- $\rho^{S}_{BH\text{-}DL/U}$: Traffic volume at Busy hour
- $\rho^{S}_{BH\text{-}DL}$: Traffic volume on the DL
- ρ_{DL} : Percentage of DL traffic

- *Traffic at BH*

➔ Type *i* end devices total traffic at BH

$$\rho^{i}_{DL/UL} = \rho^{i}_{BH\text{-}DL/UL} \; N_i$$

$\rho^{i}_{DL/UL}$: type *i* end devices total traffic at Busy hour

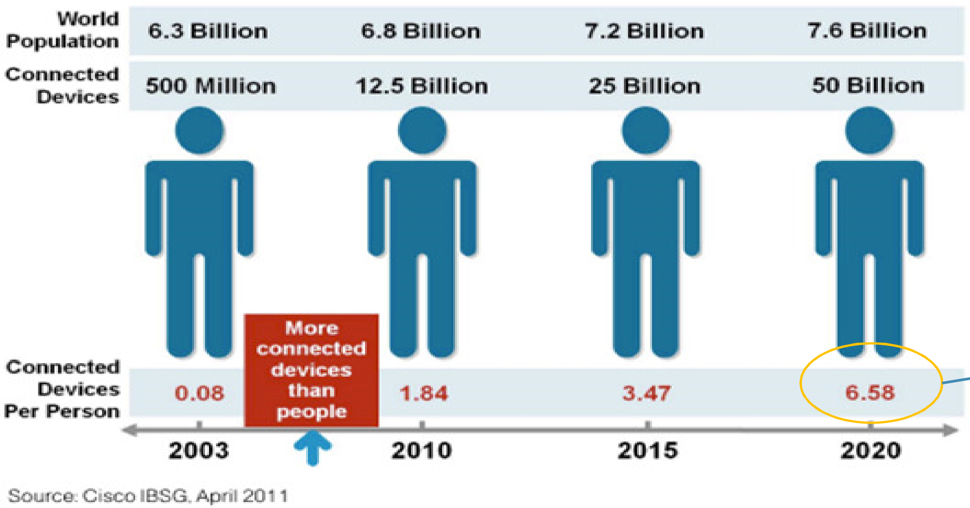
➔ Type *i* end devices throughput at BH

$$TH_{i\ BH\text{-}DL/UL} = (\rho_{i\ DL/UL}) / 3600$$

2. Dimensioning Use Case

Load assessment

The capacity of the planned network must comply with the requirements of the terms of traffic to be handled.



For **1 million people**

We can predict
7 million devices

Possible distribution in the different areas according to the number of people and the penetration

End devices	Urban area (60 %)	Suburban area (30 %)	Rural area (10 %)
7 million	4.2 million	2.1 million	0.7 million

Service and End Device Modeling

Modeling of:
- End devices (type, technology used, …)
- Sensors
- Other connected things

→ Modeling the services

❖ *Fleet Management:* The end device can send a packet in the network every **30 second** to track a vehicle

❖ *Logistic*: an end device can send a packet in the network every **5 min** to report his occupation state

❖ *Water meter*: can send a packet **once a day** to inform the water consumption

Traffic Modeling

Several parameters to consider depending on the technology

Packet size

Preamble	Payload	CRC

↓ Change according the services

Number of available channels

More channels ➔ More simultaneous connections

Throughput

Determine the time on Air ➔ Packets inter-arrival time

Gateway Capacity

Gateway capacity (packets/day, maximum throughput, …)

Use case

Assumptions

- Big City
- **Public LoRaWAN Network Dimensioning**
- Number of devices increase every year
- Total Bandwidth: **1 MHz**

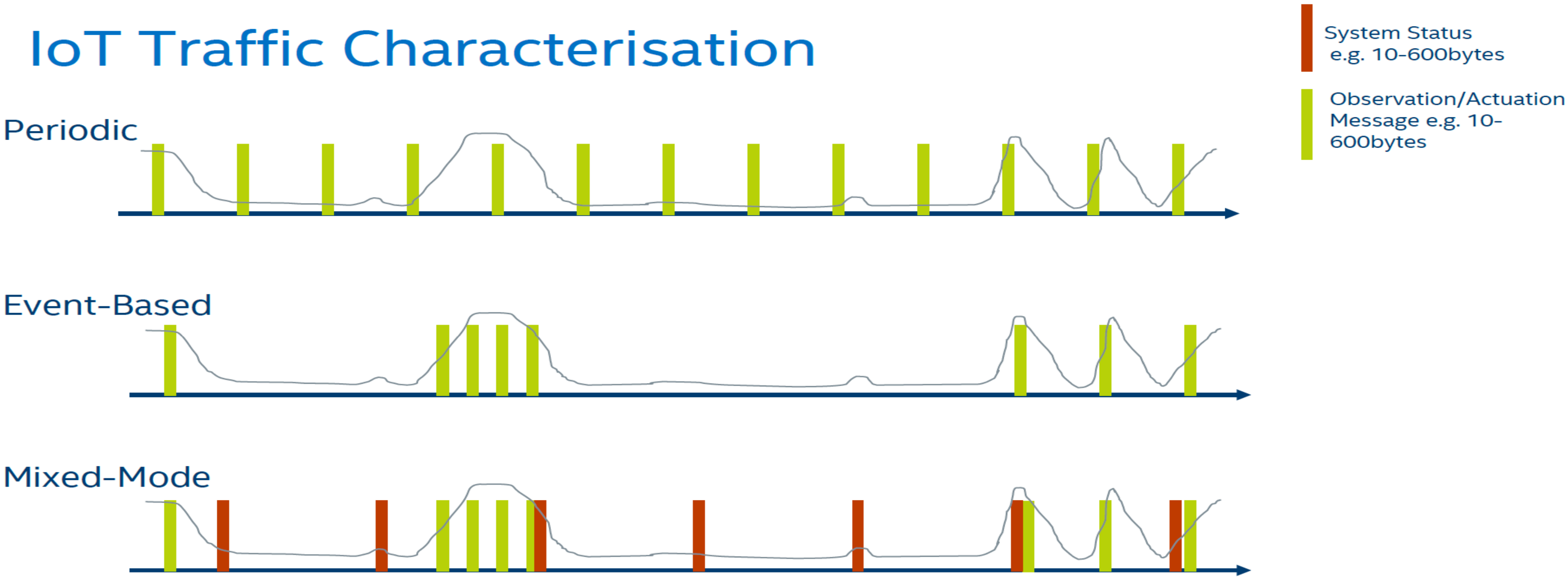
- **LoRa SX1301 Chipset**
- **Bandwidth: 125 KHz**
- **8 channels**
- **Central Frequency: 868 MHz**
- CRC enabled
- Low data rate optimization enabled

Use case

Traffic Modeling

Services	Packet transmission frequency (per hour)
Sensor	1
Metering	0,04
Alarm	1/365/24
Tracking Logistic	2
Vehicle Tracking	6
Traffic Control	60
Agriculture	1
Wearables	2
Home Automation	0,50

Profiles of traffic



Use case

Gateway Capacity

Lora Gateway **Capacity**: given in terms of **number of packets per day**.

LoRa Packet
(maximum size: 256 bytes)

Preamble	Payload	CRC
Up to 5 bytes	Min: 2 bytes	Up to 2 bytes

Payload Size (byte)	Spreading Factor	Symbol Rate	Programmed Preamble (Symbol)	Preamble Duration (ms)	Coding Rate	Number of payload Symbol	Payload Duration (ms)	Duration of packet (ms)	Single Gateway with 8 channels Capacity (Packets per day)
10	7	0,98	6	10	2	32	32	43	1 997 041
10	8	0,49	6	20	1	23	47	68	1 268 797
5	9	0,24	6	41	2	14	57	99	869 845
15	10	0,12	6	83	4	40	327	411	209 888
15	11	0,06	6	167	1	23	376	544	158 600
10	7	0,98	6	10	4	40	40	51	1 679 104
15	8	0,49	6	20	1	33	67	88	975 434
12	9	0,24	6	41	3	29	118	160	537 420
12	10	0,12	6	83	1	23	188	272	317 199

IoT Applications with Different Characteristics

Many different M2M applications with different characteristics

Example Applications	Data volume	Quality of Service	Amount of signalling	Time sensitivity	Mobility	Server initiated communication	Packet switched only
Smart energy meters	low	low	intermediate	very low	no	yes	yes
Road charging	low	low	low	low	yes	no	yes
eCall	very low	very high	very low	very high	yes	no	no
Remote maintenance	low	low	high	high	no	yes	yes
Fleet management	low	low	very high	intermediate	yes	yes	no
Photo frames	intermediate	low	high	low	no	yes	yes
Asset tracking	low	low	very high	high	yes	yes	no
Mobile payments	intermediate	low	high	very high	yes	no	yes
Media synchronisation	high	low	high	intermediate	yes	yes	yes
Surveillance cameras	very high	very high	low	very high	no	yes	yes
Health monitoring	high	high	high	very high	yes	yes	yes

very low · low · intermediate · high · very high

- There is not *one* type of M2M application with *one* set of requirements
- Operators should be able to differentiate their M2M portfolio

Source: www.itu.int/md/T09-SG11-120611-TD-GEN-0844/en

Use case

First Year

Gateway **Capacity: 1 500 000 packets per day**

Services	Packet transmission frequency (at BH)	End devices Number	Number of packets per day for one device	Burstiness Margin	Security Margin	Number of packets
Sensor	1	200	24	20%	10%	152 064
Metering	0,04	100,00	1	20%	10%	132
Alarm	0,00	100,00	1	20%	10%	132
Tracking Logistic	2	100	48	20%	10%	304 128
Vehicle Tracking	6	70	144	20%	10%	1 916 007
Traffic Control	10	150	240	20%	10%	11 404 800
Agriculture	1	200,00	24	20%	10%	152 064
Wearables	0,5	1000,00	12	20%	10%	190 080
Home Automation	0,5	300	12	20%	10%	57 024
Total Packets per day						14 176 431

Number of Gateways: **10**

Use case

Second Year

Gateway **Capacity: 1 500 000 packets per day**

Services	Packet transmission frequency (at BH)	End device Number	Number of packets per day for one device	Burstiness Margin	Security Margin	Number of packet
Sensor	1	400	24	20%	10%	304 128
Metering	0,04	200	1	20%	10%	264
Alarm	0,00	200	1	20%	10%	264
Tracking Logistic	2	200	48	20%	10%	608 256
Vehicle Tracking	6	140	144	20%	10%	3 832 013
Traffic Control	10	300	240	20%	10%	22 809 600
Agriculture	1	400	24	20%	10%	304 128
Wearables	0,5	2000	12	20%	10%	380 160
Home Automation	0,5	600	12	20%	10%	114 048
Total Packets per day						28 352 861

Number of Gateways: **19**

Use case

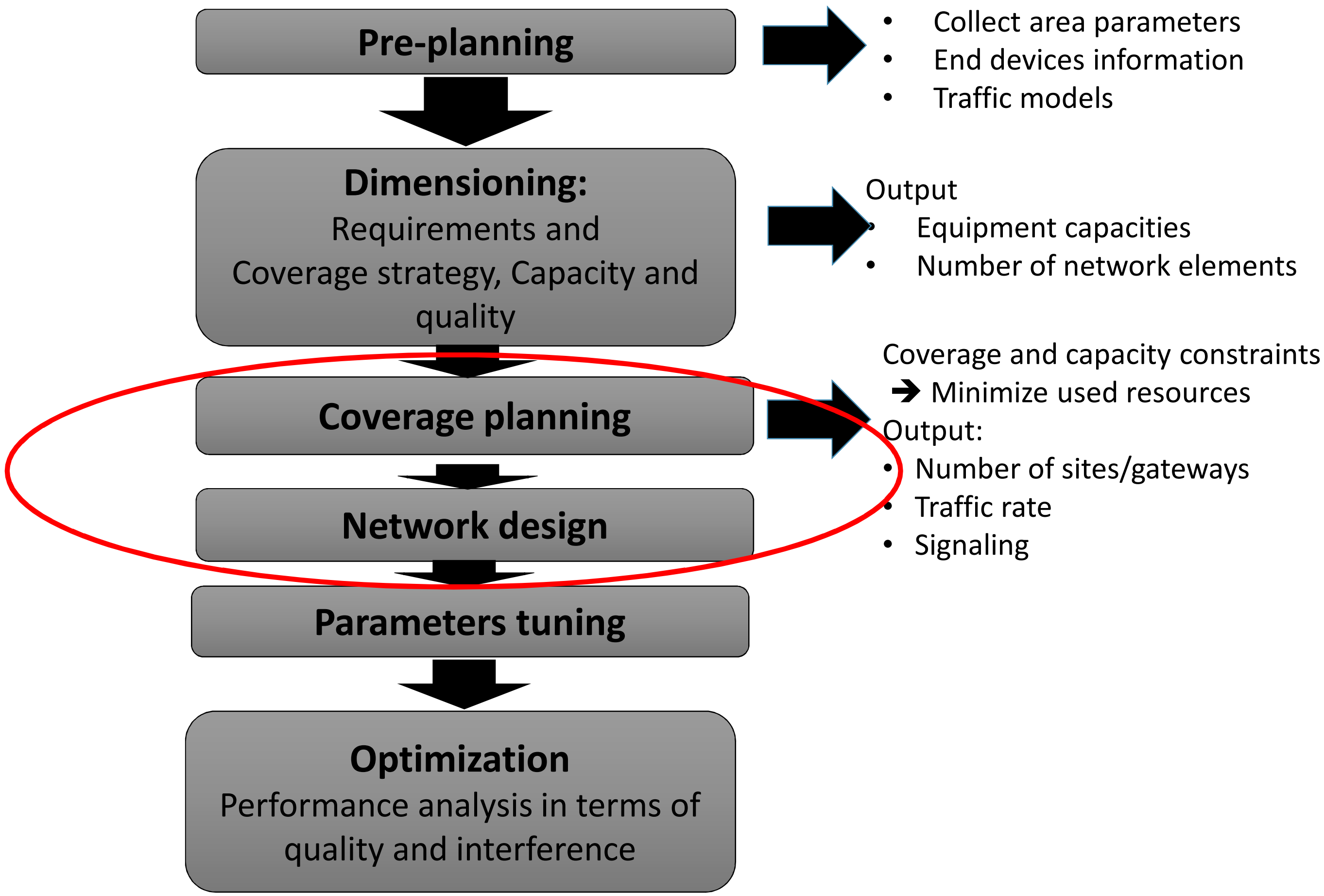
Third Year

Services	Packet transmission frequency (at BH)	End device Number	Number of packets per day for one device	Burstiness Margin	Security Margin	Number of packets
Sensor	1	800	24	20%	10%	608 256
Metering	0,04	400	1	20%	10%	528
Alarm	0,00	400	1	20%	10%	528
Tracking Logistic	2	400	48	20%	10%	1 216 512
Vehicle Tracking	6	300	144	20%	10%	8 211 456
Traffic Control	10	600	240	20%	10%	45 619 200
Agriculture	1	800	24	20%	10%	608 256
Wearables	0,5	3000	12	20%	10%	570 240
Home Automation	0,5	1200	12	20%	10%	228 096
Total Packets per day						57 063 072

Number of Gateways: **39**

3. Network planning

Wireless Network Planning Process



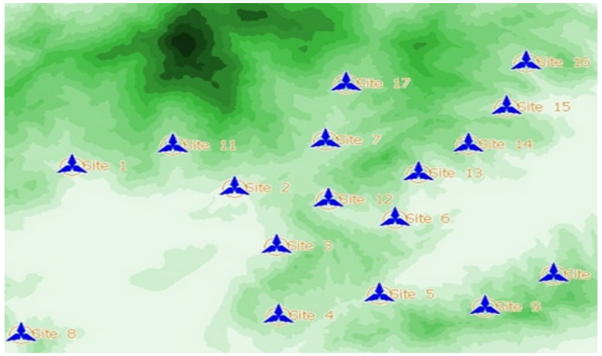
Planning overview

1. Pre-planning of radio network: ***Initial Site Selection***

Determine:

- Theoretical location of sites
- Implementation parameters (antenna type / azimuth / tilt / altitude / feeder type / length)
- Gateway parameters (as transmission power, transmission periodicity, …)

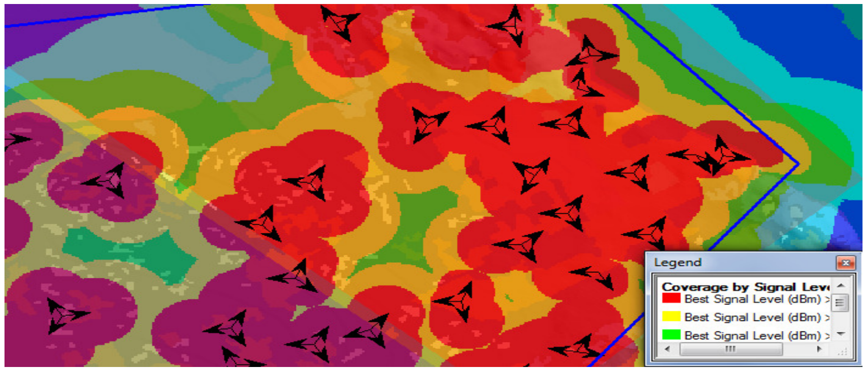
1. Based on the **network dimensioning** and **site information**.
2. An **analysis** is made to check whether the **coverage** of the system meets the requirements → the height and tilt of the antenna and the GTWs number are adjusted to optimize the coverage.
3. The system capacity is analyzed to check whether it meets the requirement.

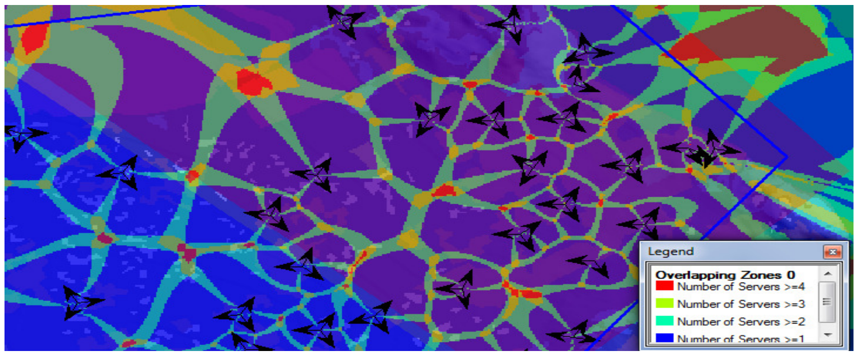


Planning overview

2. Pre-planning of radio network: ***Prediction***

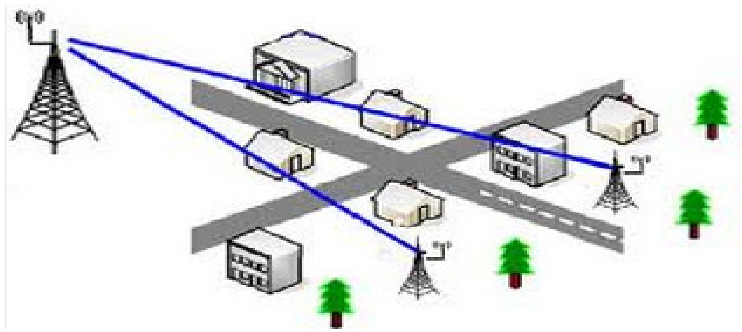
- Predict coverage results such as best serving cell, overlapping area …
- Carry out detailed adjustments (such as gateway number, gateway configuration, antenna parameters) after analyzing the coverage prediction results
- Obtain proper site location and parameters that should satisfy coverage requirements



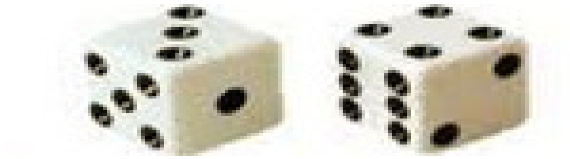


3. Cell planning of radio network: **Site survey**

- Select backup location for site if theoretical location is not available
- Take into account:
  - Radio propagation factor: situation / height / surrounding /
  - Implementation factor: space / antenna installation / transmission / power supply

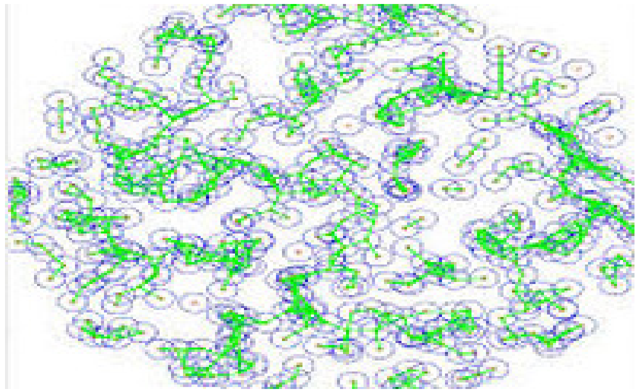


3. Cell planning of radio network: ***Simulation***



- Generate certain quantity of network instantaneous state (snapshots)
- By iteration
- Determinate gateway load, connection status and rejected reason for each end device

➔ understand network performance



PRE-PLANNING

- Choice of the area
- Choice of antennas
- Choice of equipment (GW and sensor)
- Choice of propagation model
- Frequencies choice

Coverage Planning

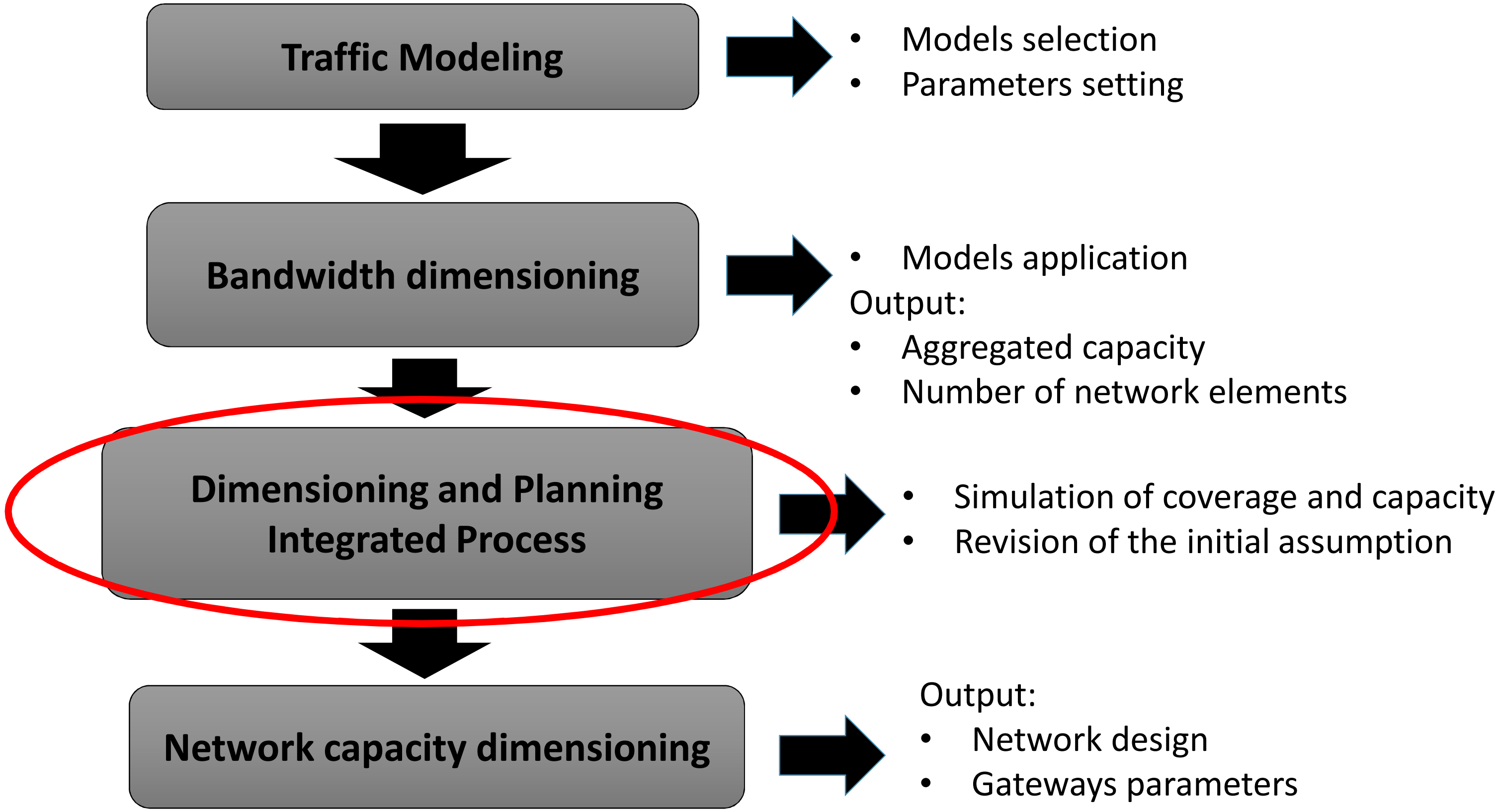
Technologies	Parameters	LORA		RPMA		SIGFOX		LTE_M	
		DL	UL	DL	UL	DL	UL	DL	UL
TX power (dBm)	TXp	20	20	20	23	24	20	40	20
TX Cable loss (dB)	TXl	-3	-1	-3	-1	-3	-1	-3	-1
TX Antenna gain, dBi	TXg	9	0	9	0	9	0	10	0
TX subtotal (dB)	TXs=TXp+ TXl+TXg	26	19	26	22	30	19	47	19
RX Sensitivity (dBm)	RXs	-137	-142	-133	-142	-129	-142	-129	-129
RX Environment noise (dB)	RXn	0	-10	0	-10	0	-10	0	-10
RX Antenna gain diversity (dBi)	RXgd	0	10	8	10	0	10	0	10
RX SubTotal (dBm)	RXs=RXgd+RXn-RXs	137	142	141	142	129	142	129	129
Total (dBm)	Tot=TXs+ RXs	163	161	167	164	159	159	176	148
Maximum allowable pathloss	Min(TotDL, TotUL)	161		164		159		148	
Range (Km)		3.5		2		3.2		2.8	
Sectorization		YES		NO		YES		YES	

- Hnode =0,3m
- HNodeB=30m
- Dense urban
- Lora &Sigfox Frequency=868MHz
- RPMA frequency =2.4 GHz
- LTE-M frequency= 1,8 GHz

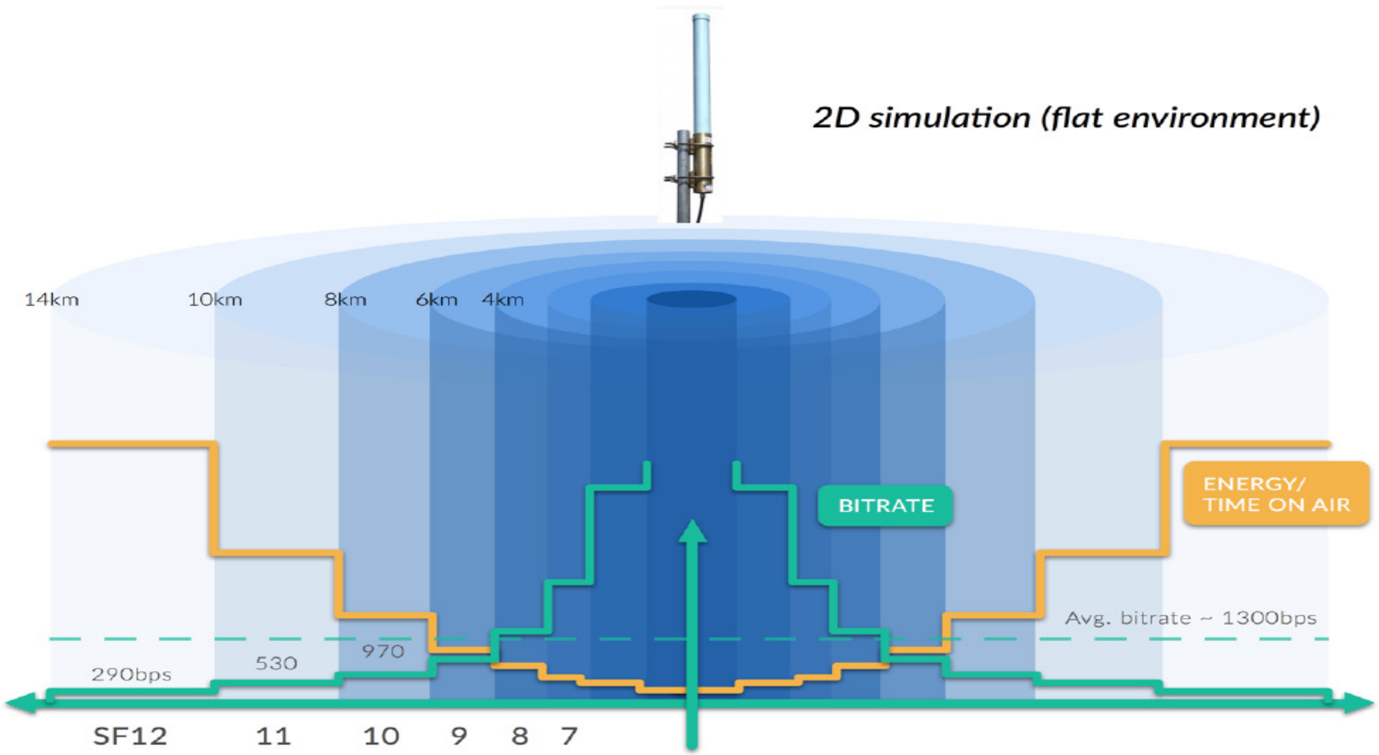
Using COST Hata model as propagation model

4. Dimensioning and Planning Integrated Process

Dimensioning Steps and Process

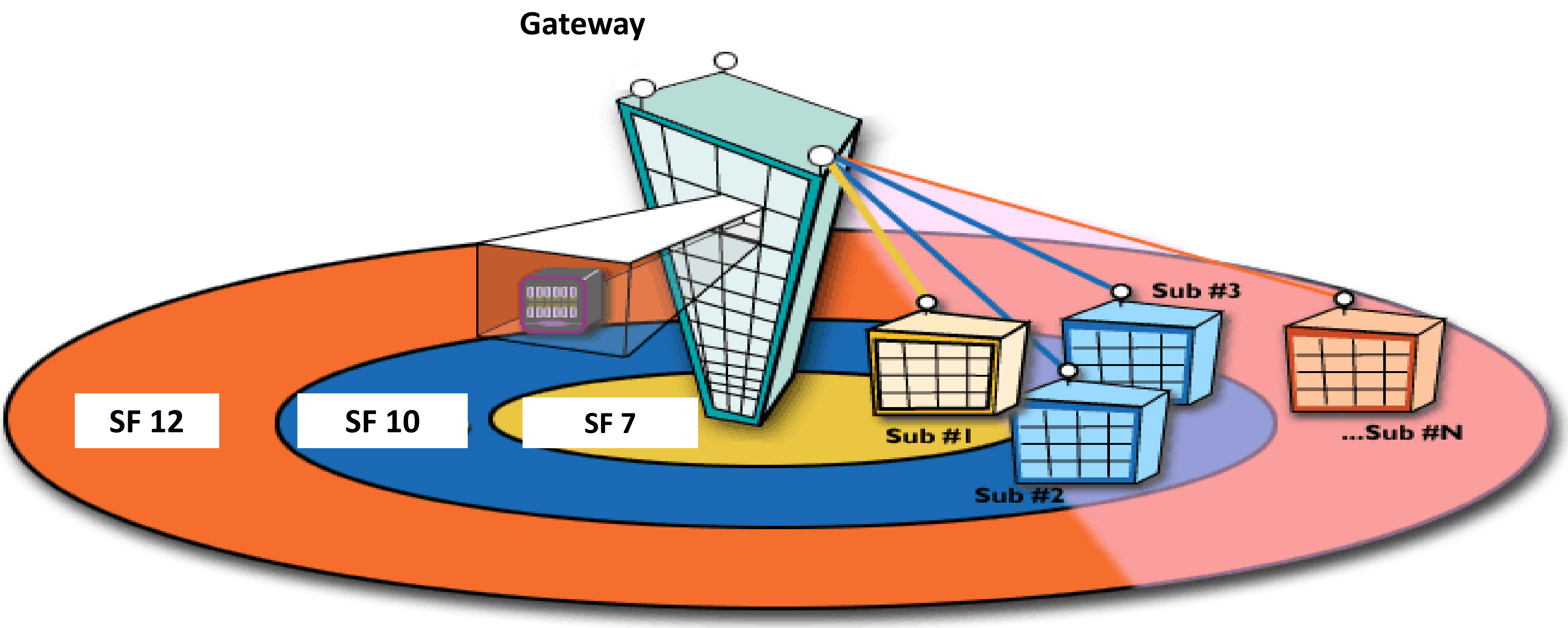


Relation between coverage and bitrate



Spreading Factor	Symbols/second	Bitrate	TOA (10 bytes, ms)	SNR limit (dB)
SF 7	976	5469	56	-7,5
SF 8	488	3125	103	-10
SF 9	244	1758	205	-12,5
SF 10	122	977	371	-15
SF 11	61	537	741	-17,5
SF 12	30	293	1483	-20

Distribution of the SF in the cell



Impact on the cell capacity

SNR	SF	Bitrate (b/s)	% of the cell	% of the population in this area	Weight
-20dB	LoRa SF12	293	15%	10%	29
-17.5dB	LoRa SF11	537	15%	10%	53
-15dB	LoRa SF10	977	10%	20%	195
-12.5dB	LoRa SF9	1758	10%	20%	351
-10dB	LoRa SF8	3125	20%	25%	781
-7.5dB	LoRa SF7	5469	30%	15%	820
Cell capacity (bit/sec)				**2231**	

Dimensioning process

Step 1: initial configuration (dimensioning and planning)

Traffic and mobility model

End devices classes

Services QoS characteristics

Services contention ratios

Transmission and protocols overheads

→ **Aggregate required capacity (Mb/s)**

Theoretical cell available bandwidth

→ **Initial number of required GTWs**

Radio planning

Radio interface characteristics

Coverage and interference requirements

End devices geographic distribution

Allocated spectrum

→ **GTW available bandwidth (Mb/s)**

Dimensioning process

Step 2: final configuration

Cell available bandwidth (Mb/s)

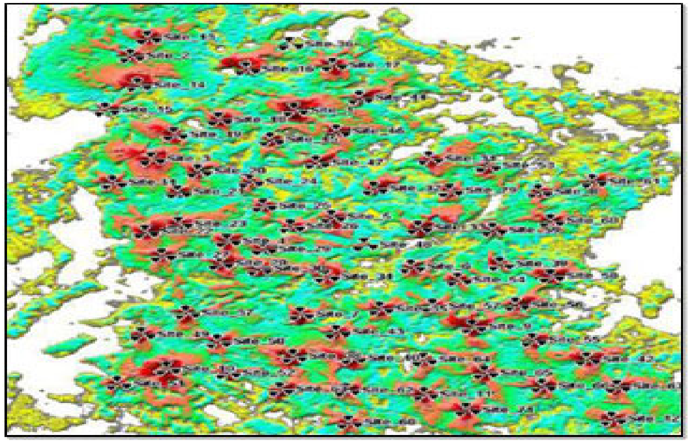
Aggregate required capacity (Mb/s)

Coverage and interference characteristics

Radio interface characteristics

New radio planning: optimization

Final number of required cells and gateway configuration



Inputs

- End devices types,
- Service usage/end devices class,
- Contention ratios/end devices class,
- End devices geographic distribution,
- Services packet sizes,
- Services and protocols overheads.

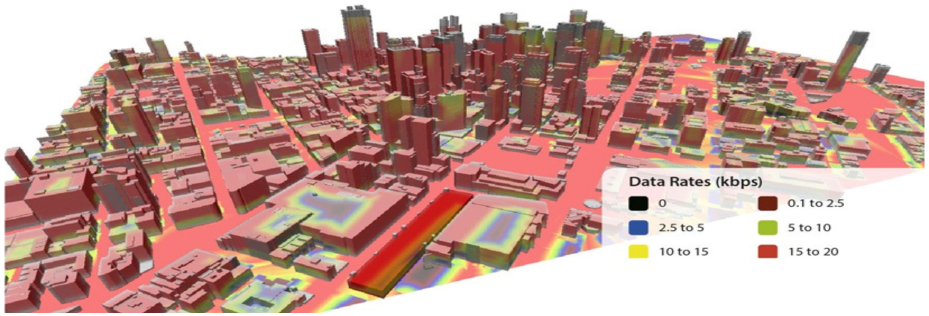
F. Case studies

IoT planning with Mentum Planet

- Introduction to Planet
- Use case 1: LoRa network planning in Tunis area
- Use case 2: Patavina Technologies network in Italy

IoT Planning

- Create demand forecasts and determine best technology options
- Dimension and simulate LPWA networks
- Optimize deployment of IoT technologies



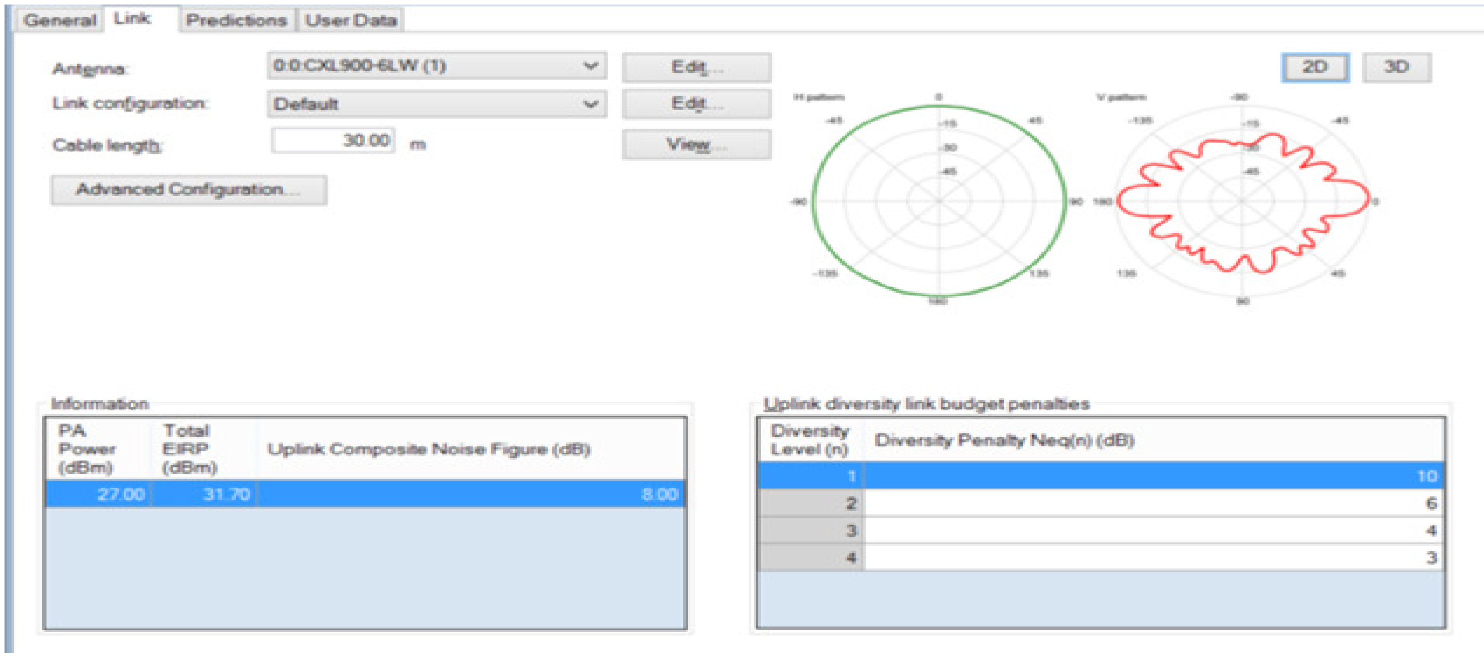
- **New IoT capabilities**. Support for IoT technologies SIGFOX and LoRa is delivered through an optional module. Network analyses (best server, signal strength, SIGFOX diversity levels, Uplink LoRa, best available modulation based on spreading factors) are all available.
- **MapInfo geographic information system**. Operators planning their network and related demand forecasts are trying to solve an RF geospatial problem. Planet is includes a leading geographic information system — MapInfo Professional™ — native to the application.
- An open platform. Planet offers multiple means to integrate 3rd-party solutions or key systems through application programming interfaces (APIs).

Different Steps

Project Setup	• Network Settings: Frequency, bands, … • Site Editor: Propagation, antenna, PA Power, … • IoT Device Editor: PA Power, Noise Figure, …
Propagation Modeling	• Geographical Data support (Elevation, clutter, height, buildings, forest, polygons, …) • Intelligent antenna management and modeling
Network Analyses	• Signal Strength, best available modulation, … • Data analytics and statistics • Scheduling and automating

Site Editor

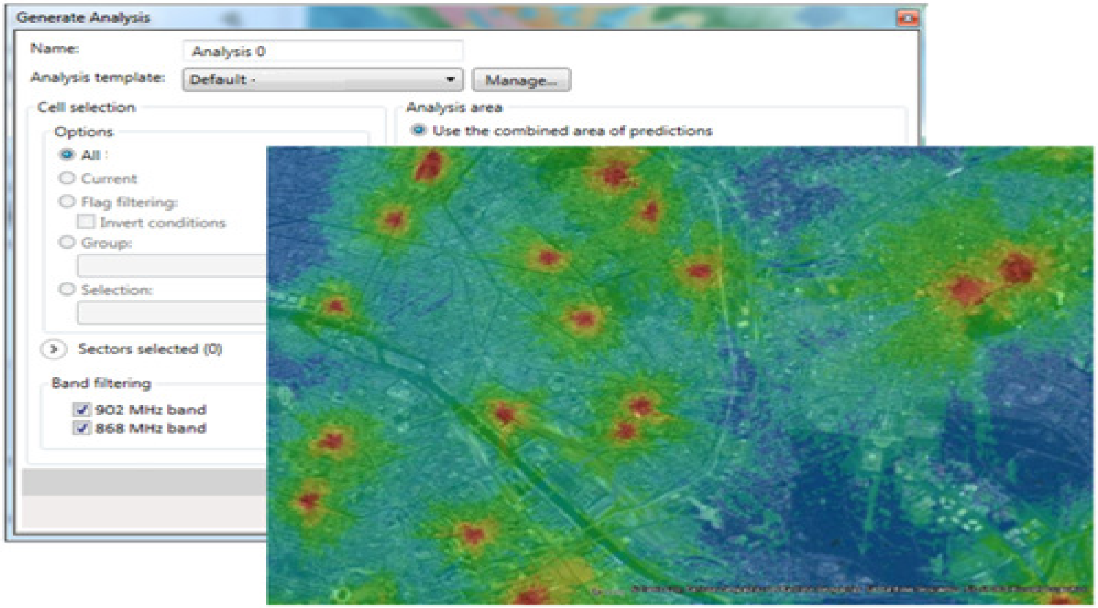
- Antenna's property
- Radiation pattern
- HBA
- Tilt
- Azimuth, ...



Network Analysis

➢ IoT-specific simulation engine with downlink and uplink analysis

- DL/UL best server
- DL/UL received signal strength
- DL/UL S/(N+I)
- DL/UL coverage (Including diversity requirement)
- Number of servers
- Nth Best Server
- LoRa Uplink capacity



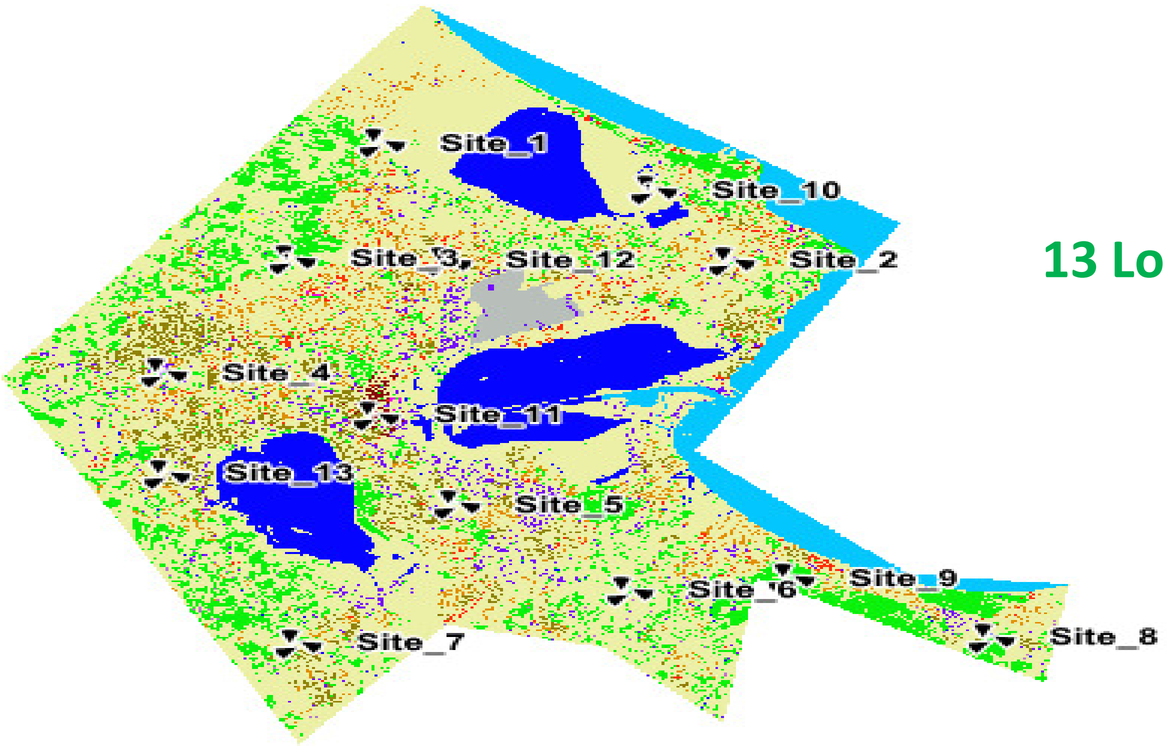
➢ Multi-threaded

Use cases

- **Introduction to Planet**
- **Use case 1: LoRa network planning in Tunis area**
- **Use case 2: Patavina Technologies network in Italy**

Use case 1

Area choice

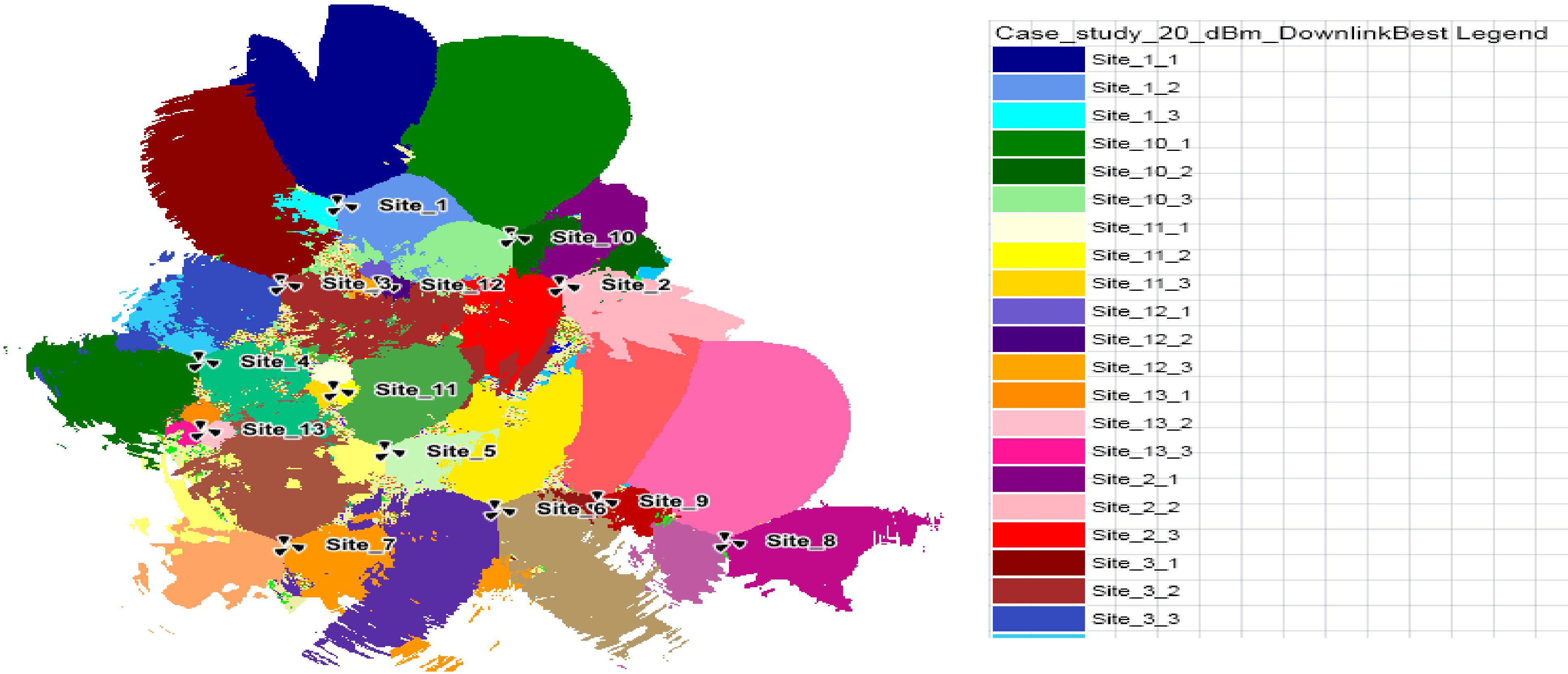


1 227.3 Km^2

13 LoRa Gateways for simulation

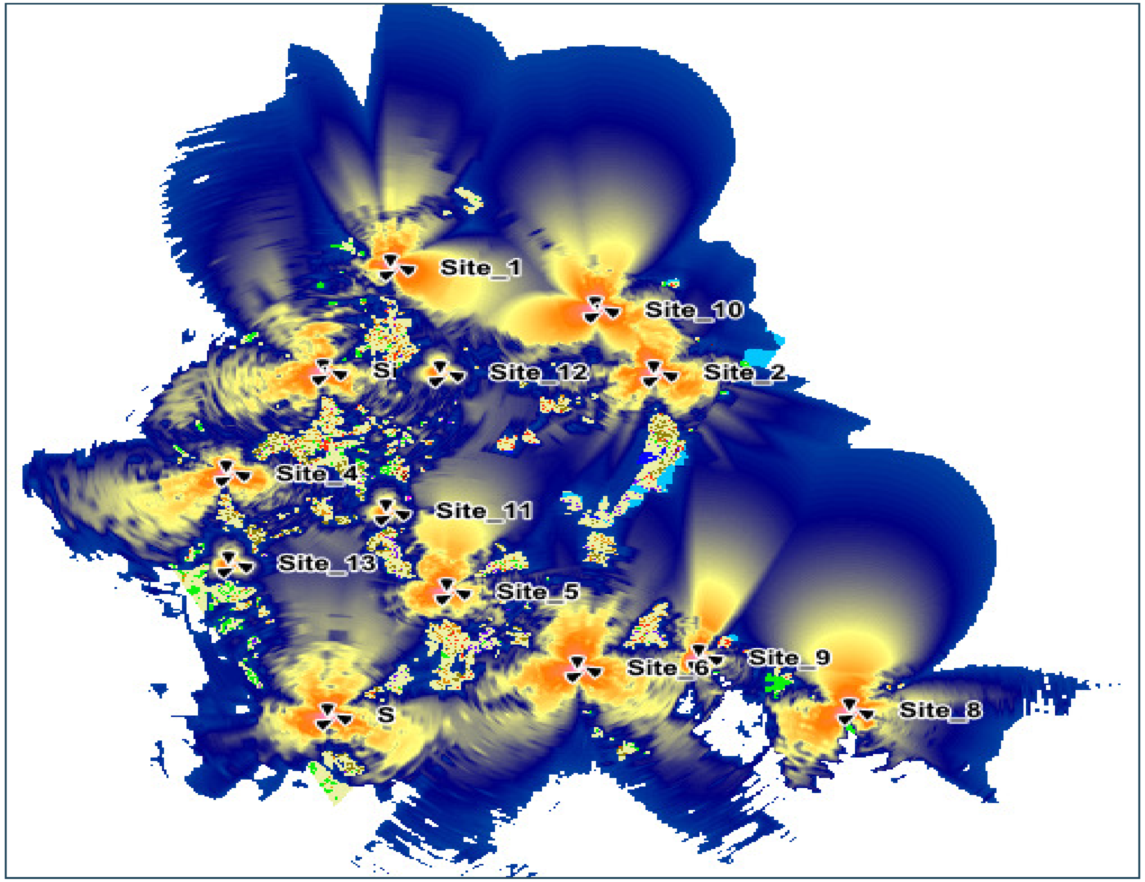
Use case 1

Downlink Best Server



Use case 1

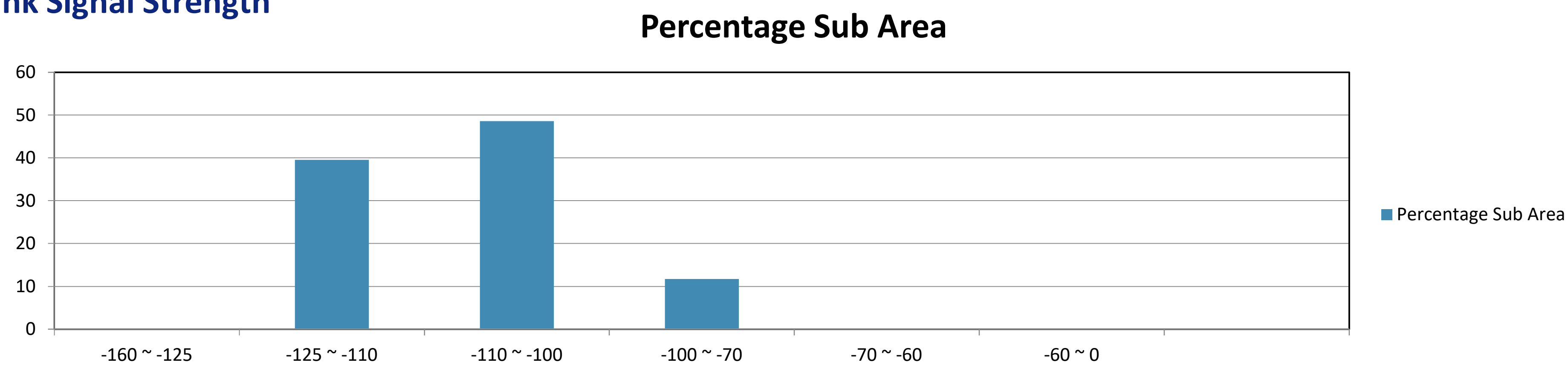
Downlink Signal Strength

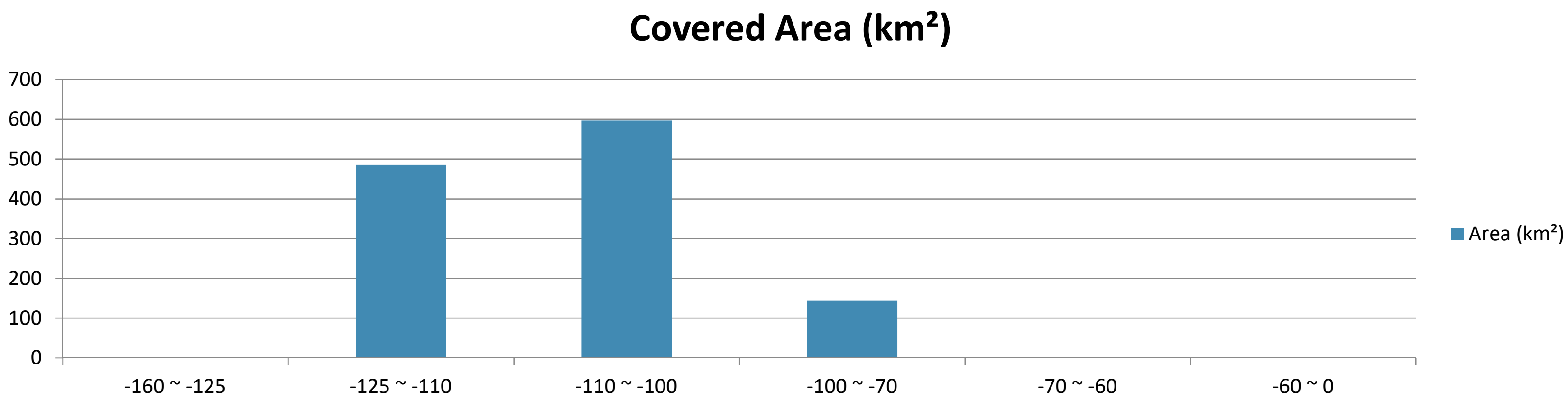


case_study_14dBm_DownlinkRecei Legend	
	-70 to -60
	-90 to -70
	-100 to -90
	-110 to -100
	-125 to -110
	-160 to -125

Use case 1

Downlink Signal Strength





Use case 1

Uplink Signal Strength

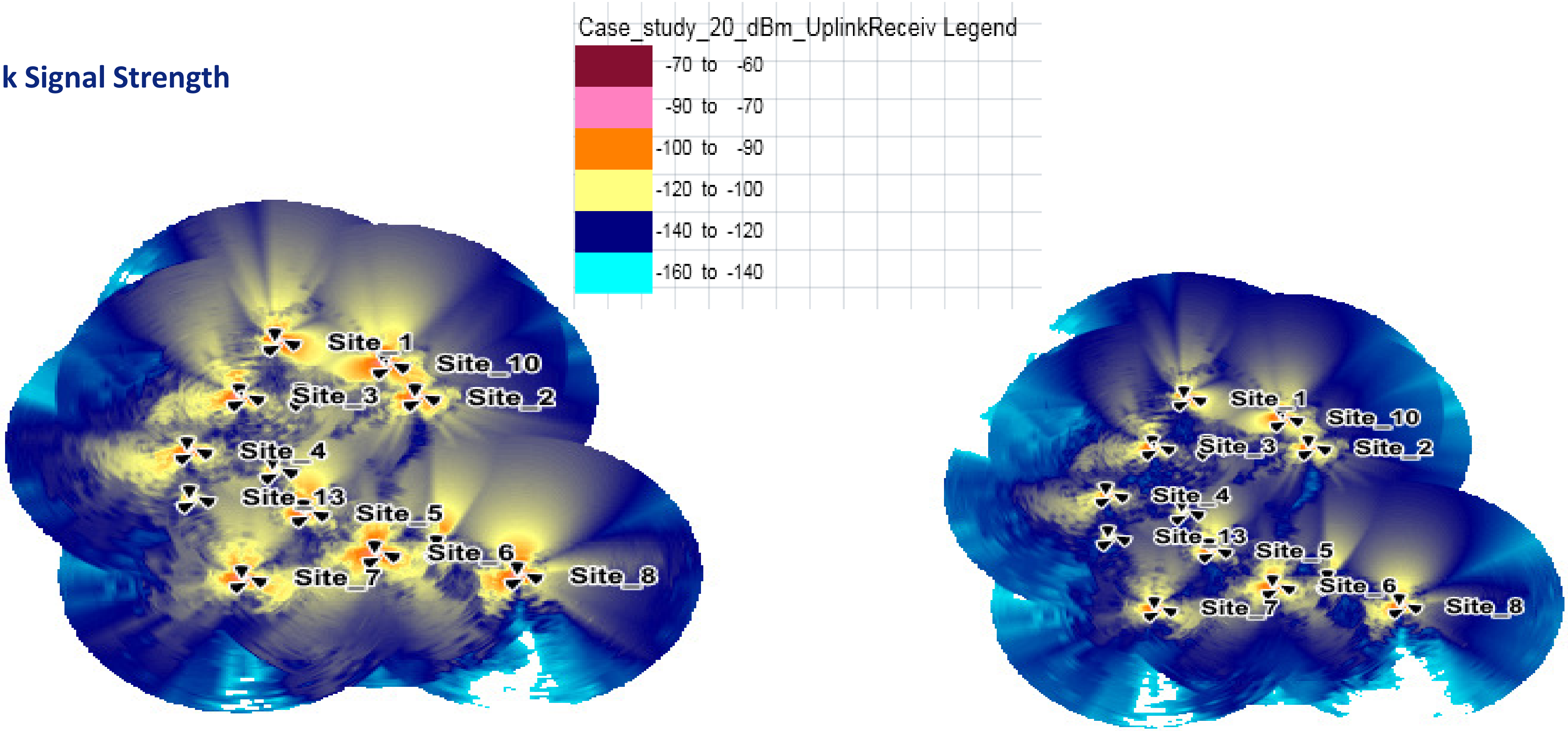
- More important to consider
- IoT devices send more packets to gateway than they receive
- LoRa End Devices Transmit Power: **14 dBm to 20 dBm**

Two use cases

14 dBm	20 dBm
Better battery economy for end devices	Better for end devices on the grid

Use case 1

Uplink Signal Strength



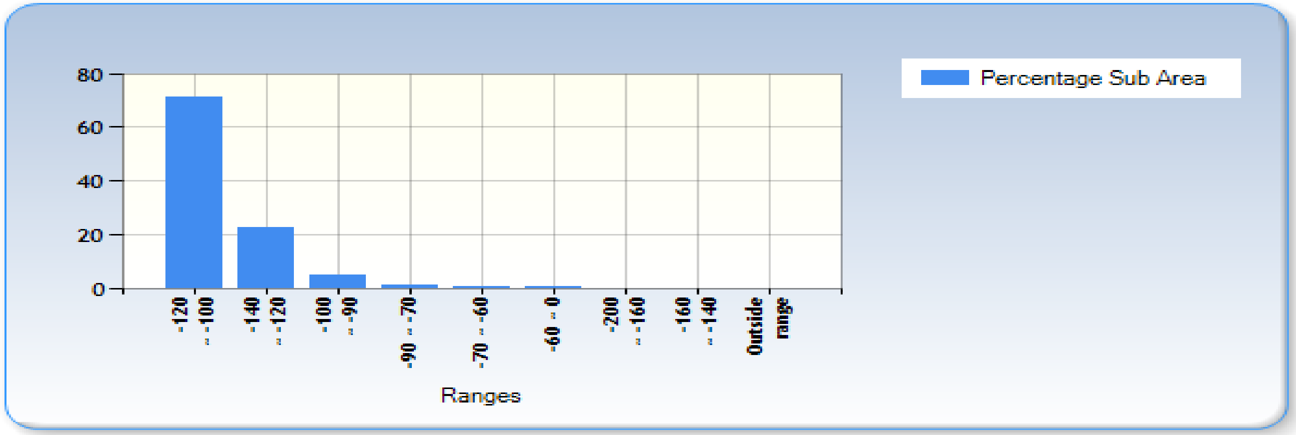
End Device Power: 20 dBm

End Device Power: 14 dBm

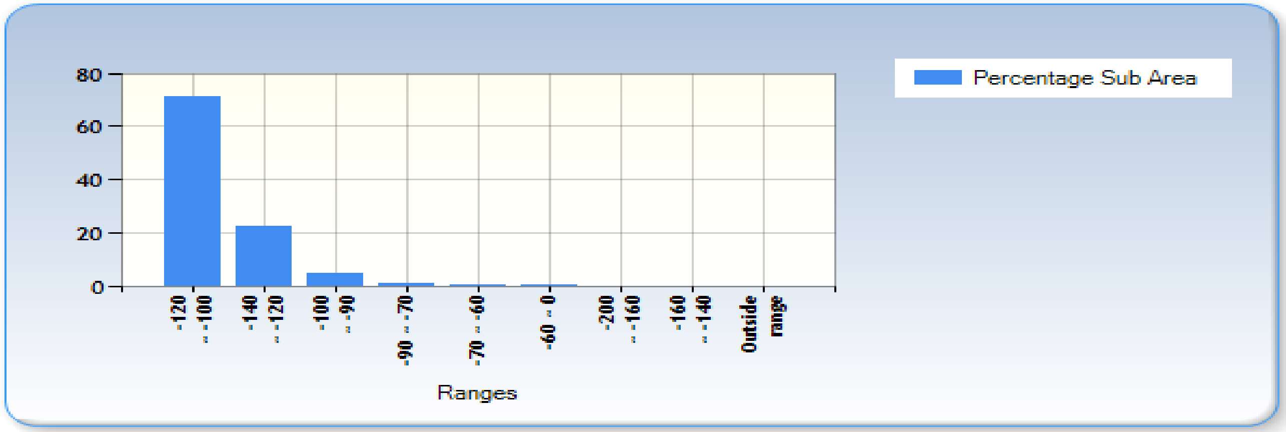
Use case 1

Uplink Signal Strength

End Device Power: 20 dBm

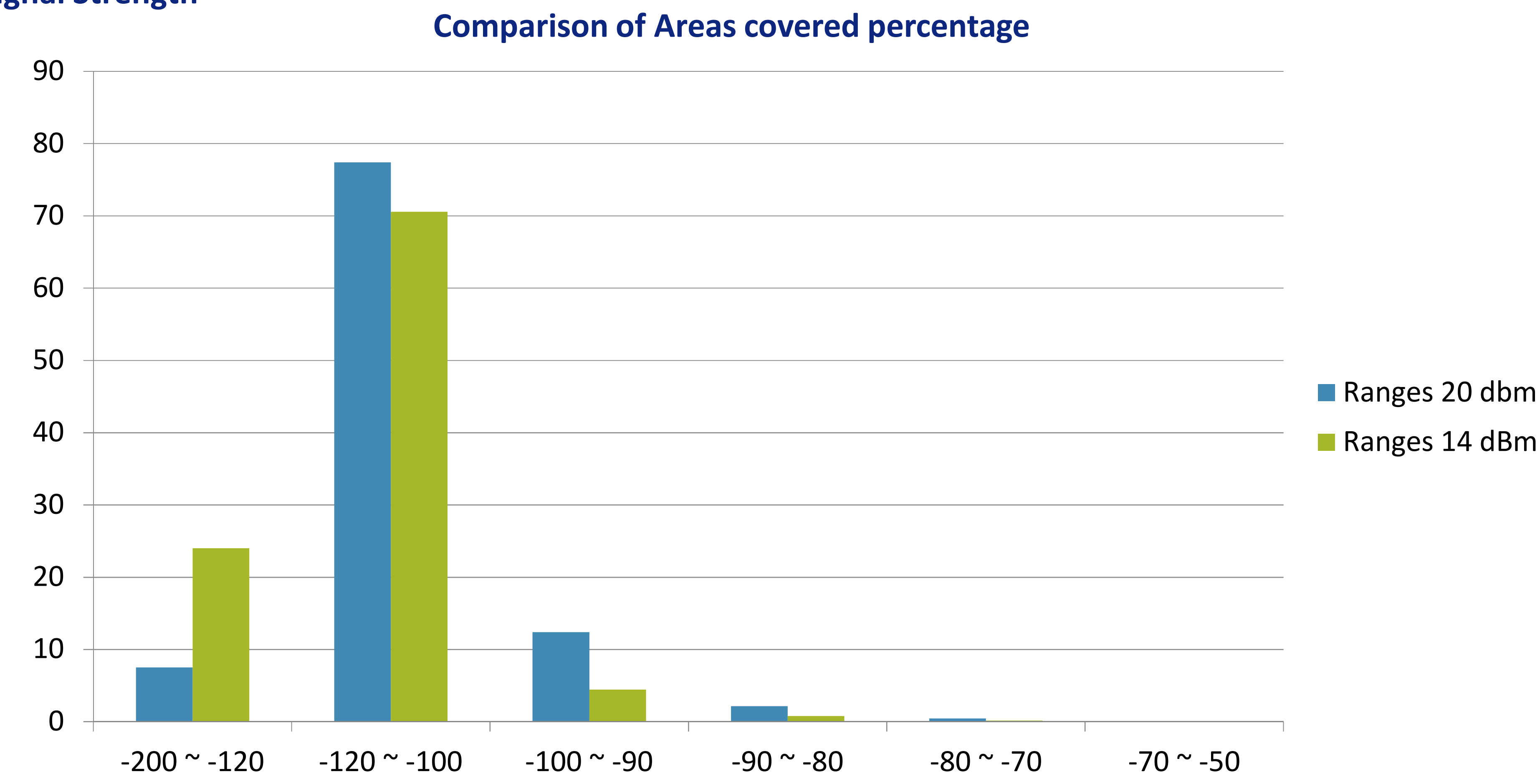


End Device Power: 14 dBm



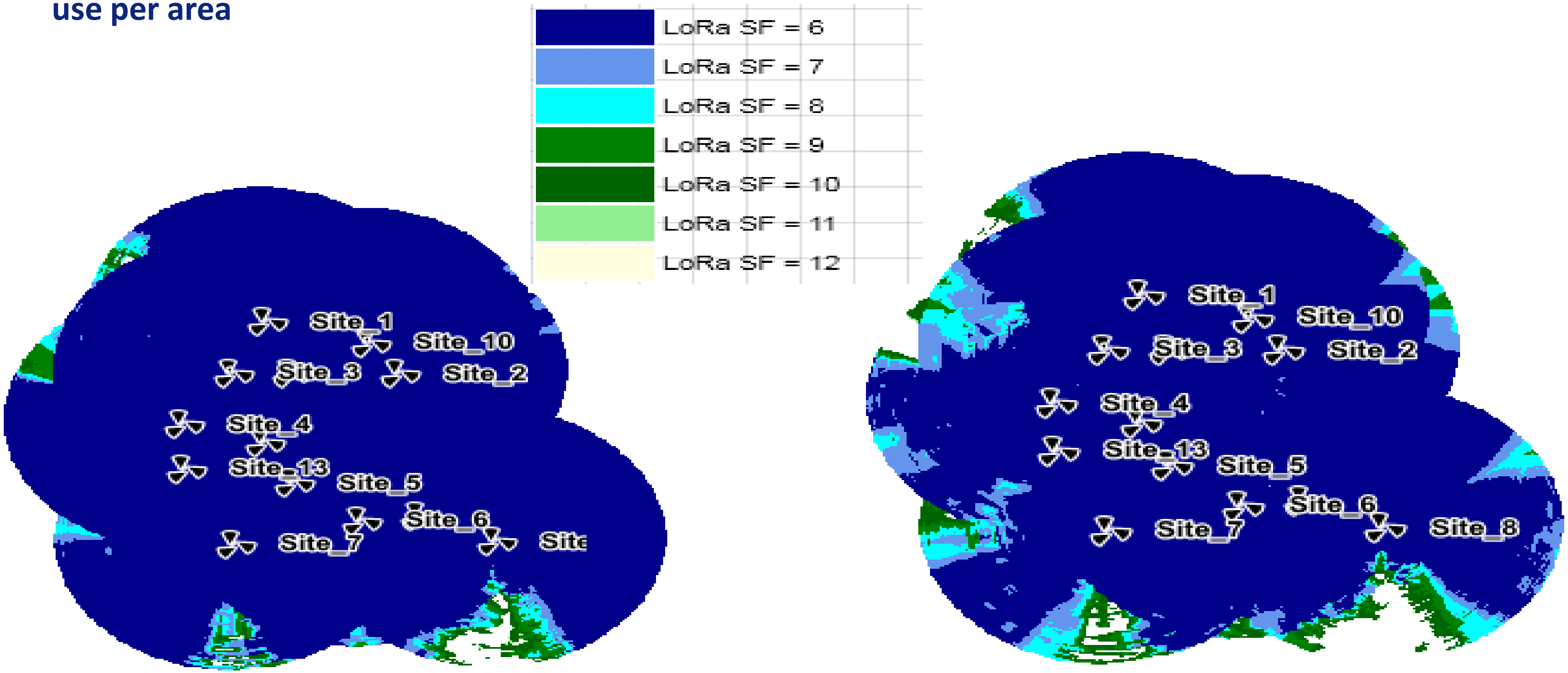
Use case 1

Uplink Signal Strength



Use case 1

Lora Spreading Factor use per area



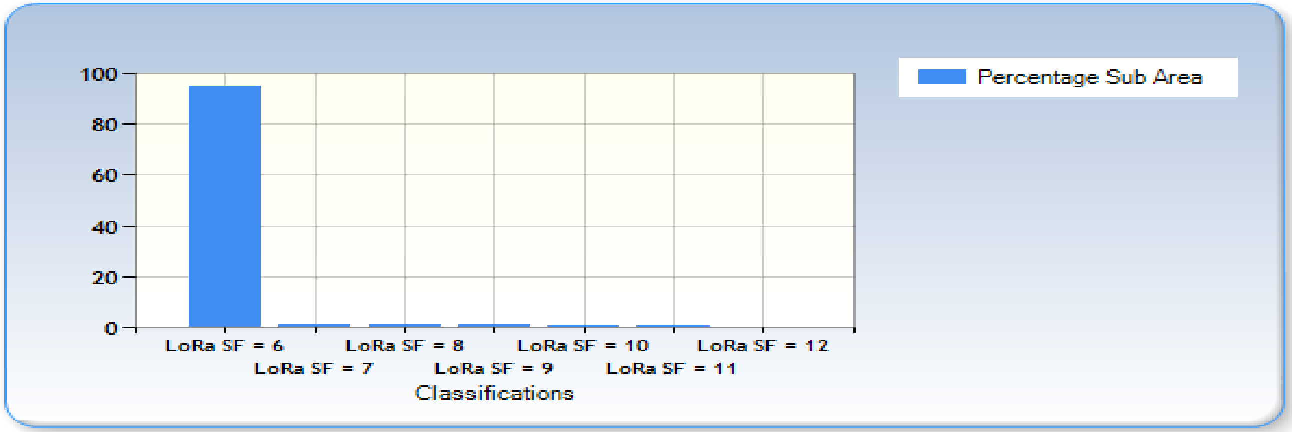
End Device Power: 20 dBm

End Device Power: 14 dBm

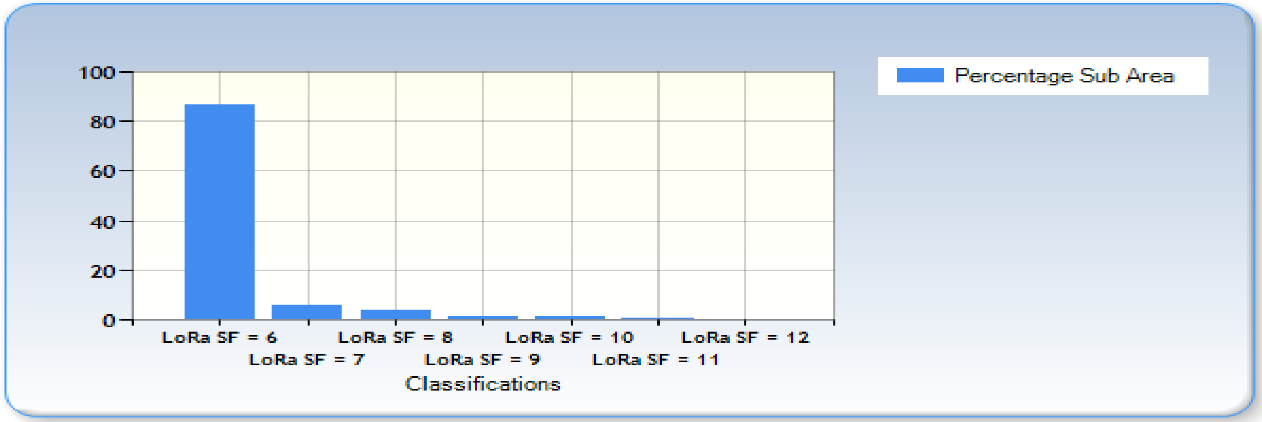
Use case 1

Lora Spreading Factor use per area

End Device Power: 20 dBm



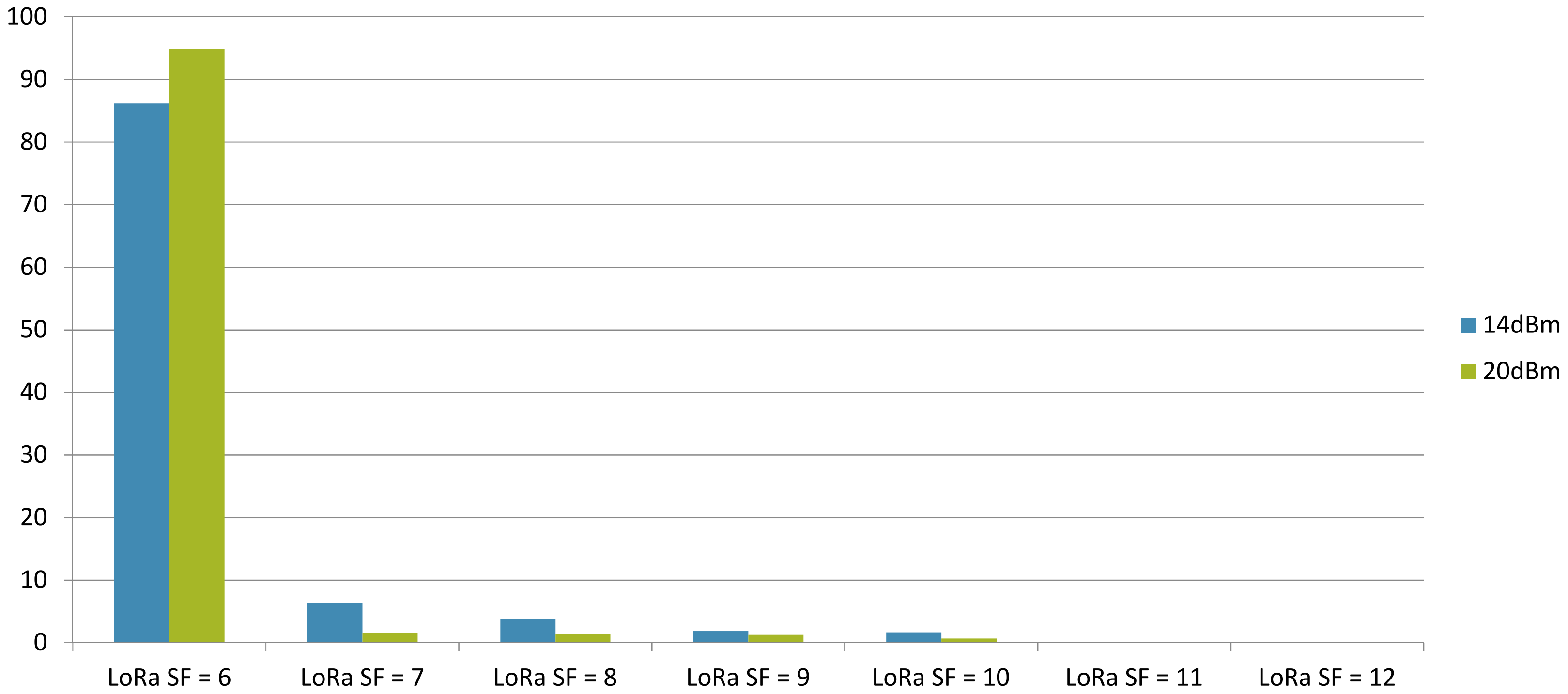
End Device Power: 14 dBm



Use case 1

Lora Spreading Factor use per area

Comparison of SF use per device transmit Power



Total Number of sites calculation

Calculate possible number of packets to be send in every area simultaneously

Distribute End Nodes per area according the different services

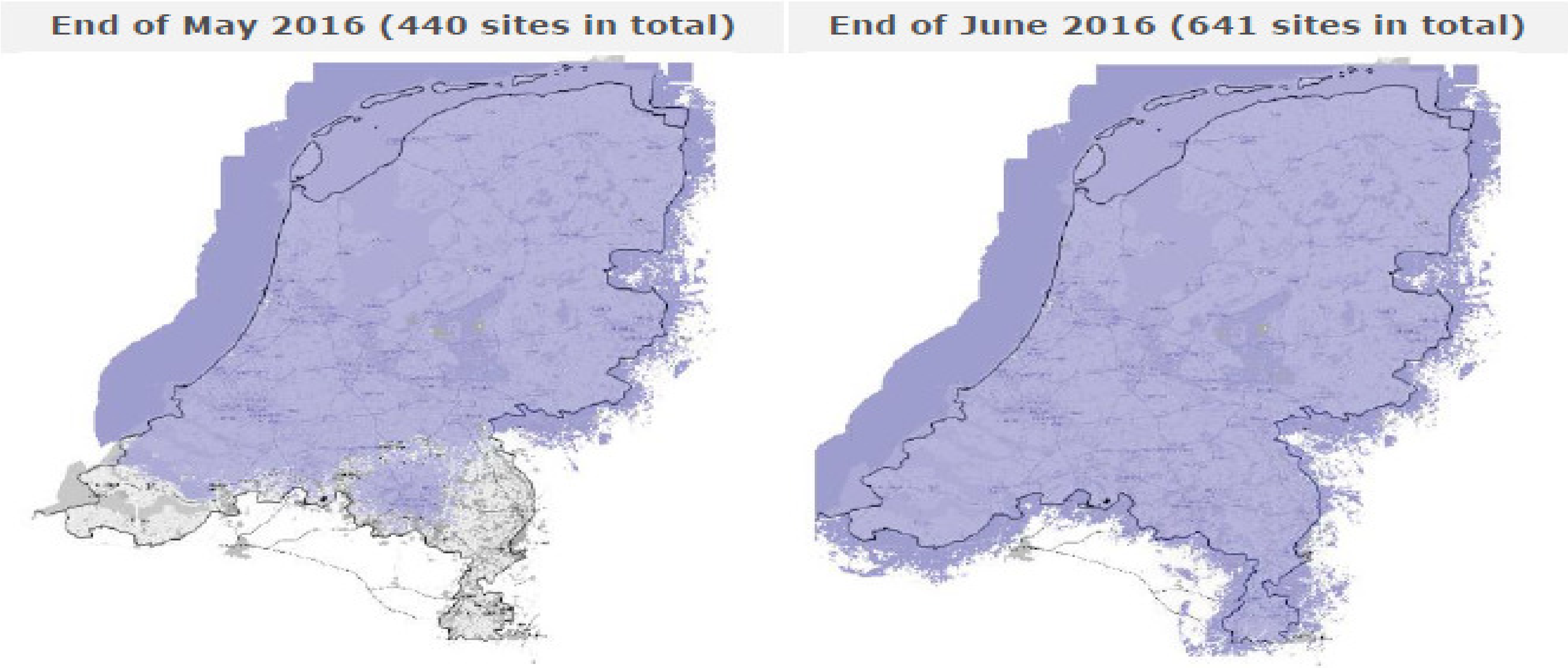
Calculate the number of gateways according the capacity of one gateway

Final Numbers of Gateways = Maximum {

Number of Gateways (coverage),

Number of Gateways (capacity) }

LoRa network coverage



KPN deployment plans for LoRa in the Netherlands, showing planned coverage for the end of May 2016 (left) and end of June 2016 (right)

- Introduction to Planet
- Use case 1: LoRa network planning in Tunis area
- Use case 2: Patavina Technologies network in Italy

Use case 2

- Private Network by Patavina Technologies in Italy
- Building with **19 floors**
- **LoRaWAN** Network
- Goal:
  - Reduce the cost related to heating, ventilation and air conditioning
  - Temperature and Humidity control

Installation

Single gateway on **ninth** floor

32 nodes

All over the building

- Open places
- Stress test

(elevators, …)

All nodes **successfully** covered

Use case 2

- Coverage analysis by Patavina Technologies in Italy
- Padova, Italy
- **LoRaWAN** Network
- Goal:
  - Assess **“worst case” coverage** (Harsh propagation conditions)
  - Conservative estimate number of gateways to cover the whole city

Use case 2

Results

Single gateway
Max radius: **2 Km**
Nominal Radius: **1.2 Km**

Padova system cell overage

- **30** gateways
- 200 000 inhabitants ➔ 7 000 per gateway
- **Adequate** for most smart city applications

Thank You