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TECHNICAL NOTE

Wireless Network capacity Test Plan

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DOCUMENT			
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Summary

1. AIM OF THE DOCUMENT

The aim of this document is to characterize the network capacity of our Wireless Sensor Networks.

This document is not intended to study radio interferences on the 2.4 GHz Band, but it helps the end user to determine the packet fluidity on a unique PAN (Personal Area Network) by stochastic calculus.

Please note that these computed values will change, depending heavily on the environment.

2. MODELLING

What is the wireless network capacity ?

In this document, the wireless network capacity is the amount of packets transmitted, received or lost during a specified period.

This Network capacity can be modeled by the following parameters:

- **LQI** Link Quality Indicator

  LQI is equivalent to Received Signal Strength Indication (RSSI).

  The LQI value is between 0 and 255.

  The more LQI is close to 255, the more the received signal power is strong.

- **PER_A** Abslute Packet Error Rate $= \sum_{k=0}^{n} \frac{\text{Packets Lost(n)}}{\text{Packets Sent}}$

  This can be local or global.

  (e.g.: 3 of 1000 Packets lost on the network/on a device, approximate)

- **PER_R** Relative Packet Error Rate $= \frac{\sum_{k=0}^{n} \frac{\text{Packets Lost n}}{\text{Packets Sent}}}{\text{Time n} - \text{Time 0}}$

  (e.g.: 3 of 1000 Packets lost on the network Per Hour)

- **MNCLP** Maximum number of consecutive lost packets

  (e.g.: 10 consecutive Packets were lost during this test, which corresponds in a time of 10 ms.)

- **Bandwidth** $\text{Bandwitdh} = \sum_{k=0}^{n} \text{BeanDevice}_n * \text{Sample Rate}_n$

  (e.g.: This network has a 400 Hz bandwidth.)

3. DEPENDENCES

There is no standard formula to compute the LQI, which depends on chipmakers.

On our RF Transceiver, there is no direct relationship between LQI and PER. In a quiet environment, PER will decrease as LQI decreases, however, if there is any interference, the PER can decrease without any change of the LQI.

RSSI (Received Signal Strength Indication) readings simply measure peak amounts of radio energy on the channel over a given period.

In this document and during test procedures, we admit:

- One RF channel is selected
- Network and PAN addresses are static.
- The quality of the RSSI is good

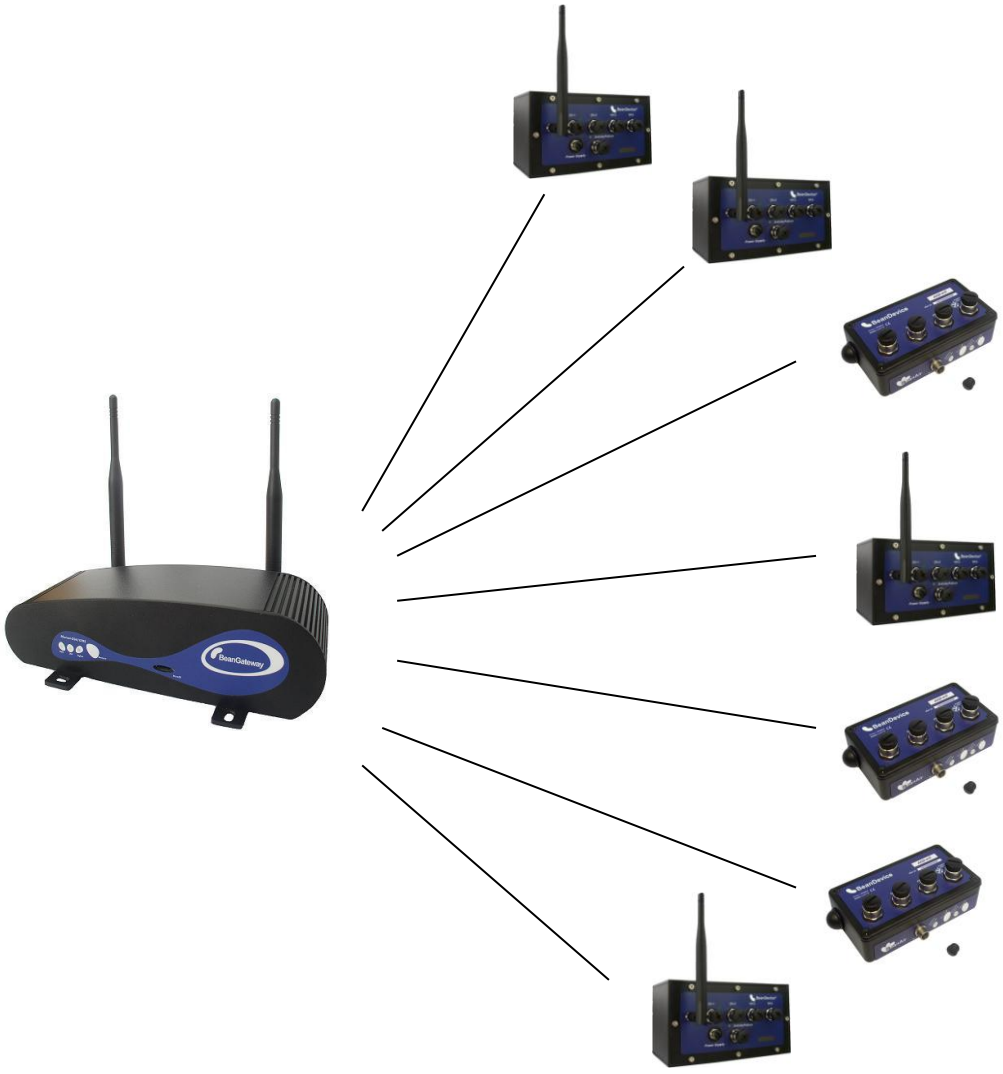
The Wireless Network capacity depends on:

- Wireless Range
- Transmission Power
- Obstacles (Water, Metal, …)
- Amount of wireless sensor.
- Sample Rate per device (0 to 5kHz)
- Amount of sensor channel. (1 to 4)
- Antenna (type, length, …)
- Interference Source (Wi-Fi , Bluetooth….)

4. INSTALLATION

The following devices and parameters are used:

Type	Model	Quantity	Version
Protocol Stack	IEEE 802.15.4	*N/A*	*N/A*
Topology	Star, Ad-Hoc	*N/A*	*N/A*
BeanGateway®	BeanGateway® Ethernet	1	v1.3
BeanDevice®	BeanDevice® AN-420	9	v1.4
	BeanDevice® AX-3D	3	v1.5
BeanScape®	BeanScape®	*N/A*	v1.9



5. TESTS PROTOCOLS

5.1 TEST: BANDWIDTH

5.1.1 Presentation

Type	Value
Title	Characterization of the Bandwidth.
ID	BANDWIDTH
Aim	Characterize bandwidth and associated parameters.
Variables	Sample Rate from 0 to 5 kHz, 1 BeanGateway® and 1 to 9 BeanDevice®.
Achieving Criteria	Bandwidth determined.
Ways	Characterize parameters, when done, use the following formula: Bandwidth = Sample Rate x ACN with PER_R >= 1%
Conditions (Constants)	Transmission power MAX, No obstacles No Wi-Fi Interferences 0.5 m < E/R Distance < 2 m. 3 activated channels per AX3D 4 activated channels per AN420

5.1.2 Results

SR: Sample Rate of each BeanDevice®

BW: Global Network Bandwith

(In Hz)

3 AX3D			
SR	BW	PER	MNCLP
50	450	0,047	1
100	900	0,125	1
180	1620	0,137	1
270	2430	0,383	1
370	3330	0,816	1
540	4860	1,593	2
800	7200	40,14	254+

6 AN420			
SR	BW	PER	MNCLP
50	1200	0,233	1
70	1680	0,295	1
100	2400	0,51	2
140	3360	3,74	2
170	4080	4,36	4
200	4800	3,02	3
250	6000	17,03	15
300	7200	26,29	254+
400	9600	33,51	254+

3 AX3D + 6 AN420			
SR	BW	PER	MNCLP
50	1650	0,044	1
70	2310	0,19	1
100	3300	2,01	2
140	4620	1,87	2
170	5610	7,51	3
200	6600	10,62	6
300	9900	52,7	254+

Global Network Bandwidth computed is a particular value.

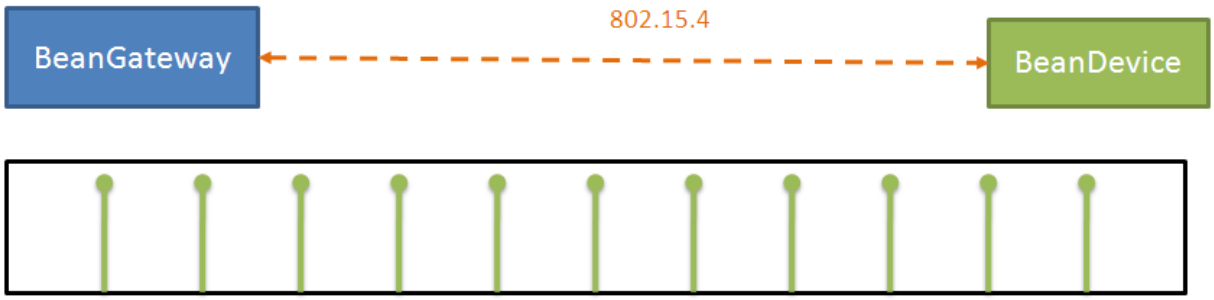
In fact, a 400 Hz Bandwidth can be obtained in different ways:

Case 1: 1 BeanDevice®, 4 channels are activated @ 100 Hz.

Case 2: 4 BeanDevice®, 1 channel is activated @ 100 Hz.

Case 3: 1 BeanDevice®, 1 channel is activated @ 400 Hz.

Case 1 and 3 have the same bandwidth.

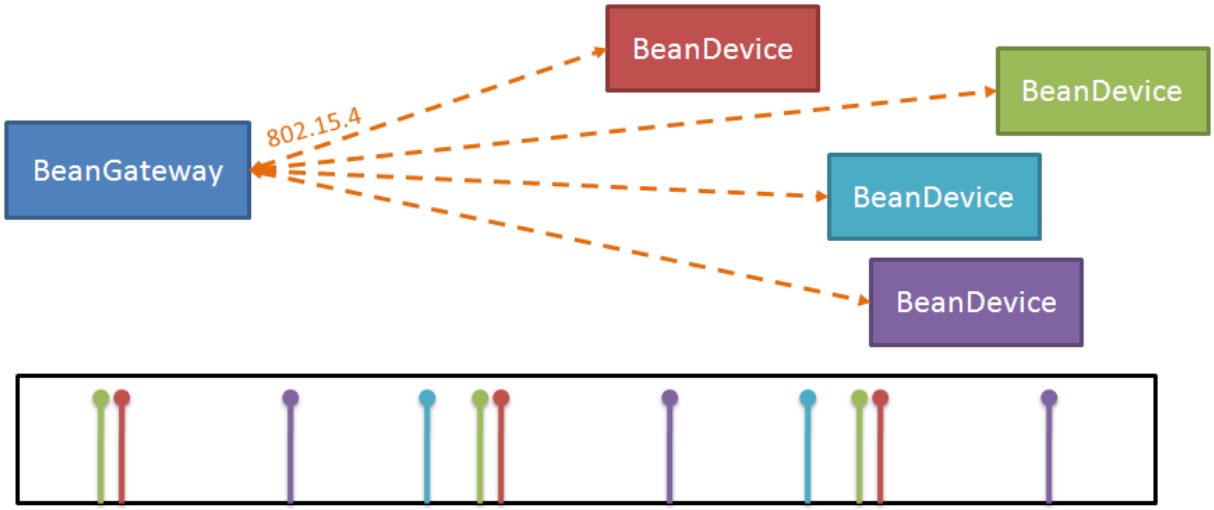


Bandwitdh = 400 Hz = 400 measure data per second = Sample Rate

Unlike case 2,

The PER can increase regarding the wireless bandwith on a wireless sensor networks

In comparison, a RF transmission on our Wireless Sensor Networks is similar to a narrowing of highway lines:



Bandwitdh = 400 Hz = 400 measure data per second ≠ Sample Rate

We might consider this formula:

In the case all BeanDevices have the same sample rate,
and are working on the same PAN in streaming mode,
the probability of a collision on a Beanair Wireless Sensor Networks
is approximately as follow:

$$P\ n\ = 100 * \frac{DTD * Chan}{Period * NDPP}^{\ n} * \frac{n(n+1)}{2}$$

Chan = Number of data acquisition channels

P = Probability of a collision

DTD = Data Transmission Duration ≈ 8 ms

SR = Sample Rate = 1/Period

n = Number of devices

NDPP = Number of data acquisition in a packet = 45

After several retries, if there is too many collisions, the packet is lost.

***Example**: Consider a wireless sensor networks with this topology:*

- *1x BeanGateway®,*
- *3xBeanDevice® AX3D with Sample Rate = 800 Hz, 3 activated channels* $P\ n\ = 46.6\%$

The same settings with Sample Rate = 50 Hz: $P\ n\ = 0.011\%$