BeanAir

TECHNICAL NOTE

Aggregation capacity of wireless sensor networks

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DOCUMENT			
Document number	**RF_TN_003 V2.2**	**Version**	V2.2
External Reference		**Publication date**	21/01/2013
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Internal Reference		**Project Code**	N.A.
Document Name	Capacity of wireless sensor network		

VALIDATION			
Function	**Recipients**	**For Validation**	**For information**
Reader	Loïc PENELON		X
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Updates

Version	Date	Author	Evolution & Status
1.0	15/12/2010	Christophe DONTEGREUIL	Document Creation, Document Update
2.0	21/12/2011	Christophe DONTEGREUIL	Document Update – Addition of new tests
2.1	02/07/2012	Christophe DONTEGREUIL	Test Updates
2.2	21/01/2013	Maxime Obr.	Document Update – New page settings
2.3	10/03/2015	Maxime Obr.	Multi-WSN architecture added
2.4	29/09/2016	Salah Riahi	Streaming Mode test results suppressed How to decrease Data loss?

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Such changes will, nevertheless be incorporated into new editions of this document.

1. TECHNICAL SUPPORT

For general contact, technical support, to report documentation errors and to order manuals, contact ***BeanAir Technical Support Center*** (BTSC) at:

tech-support@beanair.com

For detailed information about where you can buy the BeanAir equipment/software or for recommendations on accessories and components visit:

www.beanair.com

To register for product news and announcements or for product questions contact BeanAir's Technical Support Center (BTSC).

Our aim is to make this user manual as helpful as possible. Keep us informed of your comments and suggestions for improvements.
BeanAir appreciates feedback from the users of our information.

2. VISUAL SYMBOLS DEFINITION

Symbols	Definition
	***Caution or Warning** – Alerts the user with important information about BeanAir wireless sensor networks (WSN), if this information is not followed, the equipment /software may fail or malfunction.*
	***Danger** – This information MUST be followed if not you may damage the equipment permanently or bodily injury may occur.*
	***Tip or Information** – Provides advice and suggestions that may be useful when installing BeanAir Wireless Sensor Networks.*

3. ACRONYMS AND ABBREVIATIONS

LQI	Link quality indicator
PER	Packet error rate
WLAN	A wireless local area network links two or more devices over a short distance using a wireless distribution method.
WSN	Wireless Sensor Network
LOS	Line-of-sight
Mb	Mega-Bytes
Mbps	Mega-Bytes per second
RF	Radio Frequency
P_{rf}	Radio Power. (Unit : dBm)
dBm	It's an abbreviation for the power ratio in decibels (dB) of the measured power referenced to 1 milliwatt (mW): 18 dBm = 63 mW.
FTP	File Transfer Protocol is a standard network protocol used to transfer files from one host to another host over a TCP-based network.
TCP	The Transmission Control Protocol is one of the core protocols of the Internet Protocol Suite.
m	Meter(s)
RSSI	Received Signal Strength Indication
SSD	System Shock Detect

4. RELATED DOCUMENTS & VIDEOS

In addition to this technical note, please consult the related application notes, technical notes and videos:

4.1 APPLICATIONS NOTES

Document name (Click on the weblink)	Related product	Description
AN_RF_007 :" Beanair_WSN_Deployment"	All BeanAir products	Wireless sensor networks deployment guidelines
AN_RF_006 – „How to extend your wireless range"	All BeanAir products	A guideline very useful for extending your wireless range
AN_RF_005 – BeanGateway ® & Data Terminal Equipment Interface	BeanGateway ®	DTE interface Architecture on the BeanGateway ®
AN_RF_003 - "IEEE 802.15.4 2.4 GHz Vs 868 MHz"	All BeanAir products	Comparison between 868 MHz frequency band and a 2.4 GHz frequency band.
AN_RF_002 – "Structural Health monitoring on bridges"	All BeanAir products	The aim of this document is to overview Beanair® products suited for bridge monitoring, their deployment, as well as their capacity and limits by overviewing various Data acquisition modes available on each BeanDevice®.

4.2 TECHNICAL NOTES

Document name (Click on the weblink)	Related product	Description
TN_RF_013 – « OPC configuration »	BeanScape® Premium+	The aim of this document is to help deploying the OPC DA and all associated services.
TN_RF_012– « BeanDevice® battery life in streaming mode »	All the products	The aim of this document is to describe the autonomy performance of the BeanDevice® SmartSensor® and ProcessSensor® product line in streaming and streaming packet mode.
TN_RF_011 – « Coexistence of Beanair WSN at 2.4GHz »	All the products	This document aims to highlight the issues affecting co-existence of Beanair WSN (IEEE 802.15.4) in the presence of interference.
TN_RF_010 – « BeanDevice® Power Management »	All the BeanDevice®	This technical note describes the sleeping & active power mode on the BeanDevice®.
TN_RF_009 – « BeanGateway ® management on LAN infrastructure »	BeanGateway ®	BeanGateway ® integration on a LAN infrastructure
TN_RF_008 – "Data acquisition modes available on the BeanDevice®"	All the BeanDevice®	Data acquisition modes available on the BeanDevice®
TN_RF_007 – "BeanDevice® DataLogger User Guide "	All the BeanDevice®	This document presents the DataLogger feature on the BeanDevice®
TN_RF_006 – "WSN Association process"	All the BeanDevice®	Description of the BeanDevice® network association
TN_RF_005 – "Pulse counter & binary Data acquisition on the BeanDevice® SUN-BN"	BeanDevice® SUN-BN	This document presents Pulse counter (ex: energy metering application) and binary Data acquisition features on the BeanDevice® SUN-BN.
RF_TN_003- "Aggregation capacity of wireless sensor networks"	All the products	Network capacity characterization of Beanair Wireless Sensor Networks
RF_TN_002 V1.0 - Current consumption in active & sleeping mode	BeanDevice®	Current consumption estimation of the BeanDevice in active and sleeping mode
RF_TN_001 V1.0- Wireless range benchmarking	BeanDevice®	Wireless range benchmarking of the BeanDevice®

4.3 RELATED VIDEOS

All the videos are available on our Youtube channel

Beanair video link (Youtube)	Related products
Company Presentation	All
BeanGateway ® - Ethernet Outdoor version introduction	BeanGateway ® - Ethernet Outdoor version introduction
BeanGateway ® – Ethernet Indoor version presentation	BeanGateway ® Ethernet Indoor version
BeanDevice® AN-XX wireless range demonstration	BeanDevice® AN-XX & BeanDevice® AN-XX Extender
BeanDevice® AN-XX presentation	BeanDevice® AN-XX & BeanDevice® AN-XX Extender
BeanDevice® AX-3D presentation	BeanDevice® AX-3D
BeanDevice® HI-INC presentation	BeanDevice® HI-INC
BeanDevice® AX-3DS presentation	BeanDevice® AX-3DS
BeanScape® – WSN supervision software	BeanScape®
BeanGateway ® Ethernet/LAN Configuration, directly connected to the Laptop/PC	BeanGateway ®
Wireless sensors profile deletion from the BeanGateway ® Database	All

5. AIM OF THE DOCUMENT

Like a highway that is tightly tucked between a mountain cliff and a lake or an ocean, WSN (Wireless Sensor Networks) are subject to limitations due to a similar lack of a physical resource –namely wireless bandwidth. Like congested road systems in highly populated metropolitan areas, WSN are unequally solicited by a various type of wireless sensors (temperature, tilt, vibration…). One way or another, we need to share the wireless bandwidth, just as we share the public road and highway systems.
The aim of this document is to characterize the aggregation capacity of Beanair WSN.
This document is not intended to study radio interferences on the 2.4 GHz Band, but it helps the end user to determine the network bandwidth on a WSN by stochastic calculus.
"Streaming packet" data acquisition mode was used during these tests.

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

6. WSN MODELING

Aggregation capacity of WSN includes the amount of data packets transmitted, received or lost during a short period.

The capacity of WSN 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.
As close to 255 is the LQI, higher is the received signal power.

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

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

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

7. COEXISTENCE AND INTERFERENCE WITH WIFI NETWORK

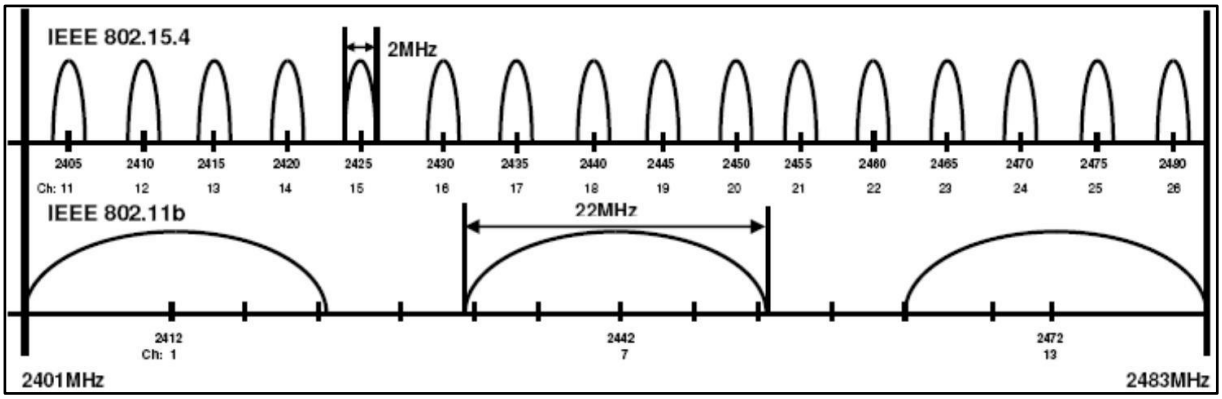

Figure 1: Wifi and IEEE802.15.4 spectrum

Frequency Offsets		IEEE 802.11b/g		
		Channel 1 2412 MHz	**Channel 7** 2442 MHz	**Channel 13** 2472 MHz
IEEE 802.15.4	**Channel 15** 2425 MHz	13 MHz	17 MHz	47 MHz
	Channel 16 2430 MHz	18 MHz	12 MHz	42 MHz
	Channel 21 2455 MHz	43 MHz	13 MHz	17 MHz
	Channel 22 2460 MHz	48 MHz	18 MHz	12 MHz

Figure 2: Wifi and IEEE802.15.4 frequency offsets

For further information, please read the following technical note:

TN_RF_011 – "Co-existence of Beanair WSN at 2.4 GHz"

8. RELATIONSHIP BETWEEN RF PARAMETERS

- There is no standard formula to compute the LQI, which depends on chipmakers.
- In a quiet environment, PER will decrease as LQI decreases, however, if there is any interference, the PER can decrease with no significant changes observed on the LQI.
- RSSI is an indication of the power level being received by the antenna. Generally, the higher the RSSI level is the stronger the signal.

<u>During the test procedures, we admit:</u>

- One RF channel is selected
- Network and PAN addresses are static.
- RSSI value is high

<u>Aggregation capacity of a WSN depends on the following influence factors:</u>

- Wireless Range
- RF Transmission Power
- Obstacles (Water, Metal, …)
- WSN density (number of BeanDevice® on the same network)
- Sampling Rate per BeanDevice® (0 to 3kHz)
- Number of sensor channel on the same BeanDevice® (1 to 4)
- Antenna (type, length, …)
- Interference Source (Wi-Fi, Bluetooth….)

9. TEST BED SETUP & METHODOLOGY

9.1 TEST EQUIPMENT DESCRIPTION

The test bed consisted of the following devices under test (DUT):

- **A BeanGateway® Indoor Ethernet Version:**
  - Powered by the external power supply
  - A 5.5 dBi antenna was used
- **BeanDevice® AX-3D (+/- 2g)**
  - Powered by internal battery
- **BeanDevice® HI-INC (15° et 30° Monoaxis and Biaxis)**
  - Powered by internal battery
- **BeanDevice® AN420**
  - Powered by its own battery
  - A 2dBi Antenna was used
- **Laptop with the BeanScape® software installed**

Type	Product Type	Quantity	Number of sensor channels	Soft Version
Protocol Stack	IEEE 802.15.4		/	
Topology	Star Network		/	
BeanGateway®	BeanGateway® Ethernet	1	/	V2.0
BeanDevice®	BeanDevice® AN-420	6	4	v2.5
	BeanDevice® HI-INC	1	2	v2.5
	BeanDevice® AX-3D	5	3	V2.5
BeanScape®	BeanScape®	1	/	1.24.1777.15

Table 1: Test Equipment List

9.2 METHODOLOGY

- "Streaming packet" mode function is evaluated during these tests plan.
- Network behavior will be studied with different sampling frequency.
- Each test iteration was run with a 10 minutes duration, and each test repeated three times to ensure repeatability of results;
- The distance observed between the BeanDevice® and the BeanGateway® is 1 meter.

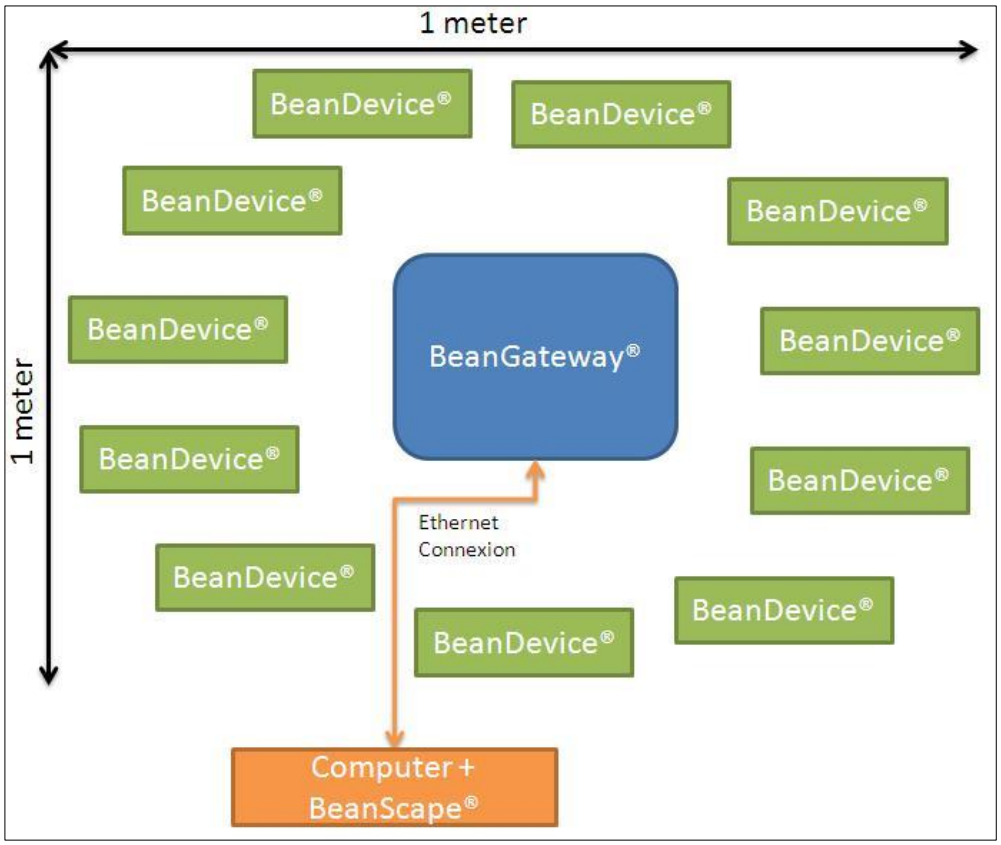

Figure 3: Network deployment presentation

For further information about the streaming packet mode, please read the technical note:

TN_RF_008 – "Data acquisition modes available on the BeanDevice®"

10. TEST RESULTS WITH STREAMING PACKET MODE

All the BeanDevice® were configured with the same sampling rate.

10.1 WSN WITH THREE BEANDEVICE® AX-3D

BeanDevice® Sample Rate (Hz)	Global Network sampling rate (Hz)	PER 1 (%)	PER 2 (%)	PER 3 (%)
25	225	7,7	7,1	8,5
50	450	8,1	7,5	9,1
75	675	10,7	9,9	13,9
100	900	11,3	10,7	16

Table 2: Three BeanDevices AX-3D

10.2 WSN WITH FIVE BEANDEVICE® AX-3D

BeanDevice® Sampling Rate (Hz)	Global Network sampling rate (Hz)	PER 1 (%)	PER 2 (%)	PER 3 (%)	PER 4 (%)	PER 5 (%)
25	375	7	6,4	7,3	9,6	9,2
50	750	8	8	10	20	28
75	1125	12	18	17	28	30
100	1500	27	30	29,5	52,2	45,8

Table 3: Five BeanDevices AX-3D

10.3 WSN WITH FIVE BEANDEVICE® AN420

BeanDevice® Sampling Rate (Hz)	Global Network sampling rate (Hz)	PER 1 (%)	PER 2 (%)	PER 3 (%)	PER 4 (%)	PER 5 (%)
25	500	21	18	26	10	24
50	1000	38	15	37	8	20
75	1500	15	22	32	22	34
100	2000	43	38	42	19	28

Table 4: Five BeanDevices AN-420

10.4 WSN WITH TWO BEANDEVICE® AX-3D AND THREE BEANDEVICE® AN420 WITH THE SAME SAMPLING RATE

BeanDevice® Sampling Rate (Hz)	Global Network sampling rate (Hz)	AX3D PER 1 (%)	AX3D PER 2 (%)	ANXX PER 3 (%)	ANXX PER 4 (%)	ANXX PER 5 (%)
25	450	4	7	15	16	14.5
50	900	8.5	15.5	25	24	29
75	1375	28	22	20	19	23
100	1800	34	43	17.5	22	36

Table 5: Two BeanDevices AX-3D & Three BeanDevices AN-420

10.5 TESTS SUMMARY

PER

- PER on each BeanDevice® is increasing regarding to the global bandwidth.
- PER on each BeanDevice® is not necessary increasing proportionaly while the global bandwidth increases.
- A BeanDevice® can have a higher PER value even if its sample rate is lower.

11. MULTI-WSN ARCHITECTURE

Network aggregation capacity can be increased by connecting several BeanGateway® to the BeanScape® software (Premium or Premium+ versions). Each BeanGateway® will manage its own WSN.

BeanGateway® IP will be allocated automatically by a LAN Router.

Several rules should be followed in order to avoid data collisions:

- The distance between each BeanGateway® should be at least 2 meters;
- If the different WSN are close to each other, allocate different Radio Channels to each WSN;

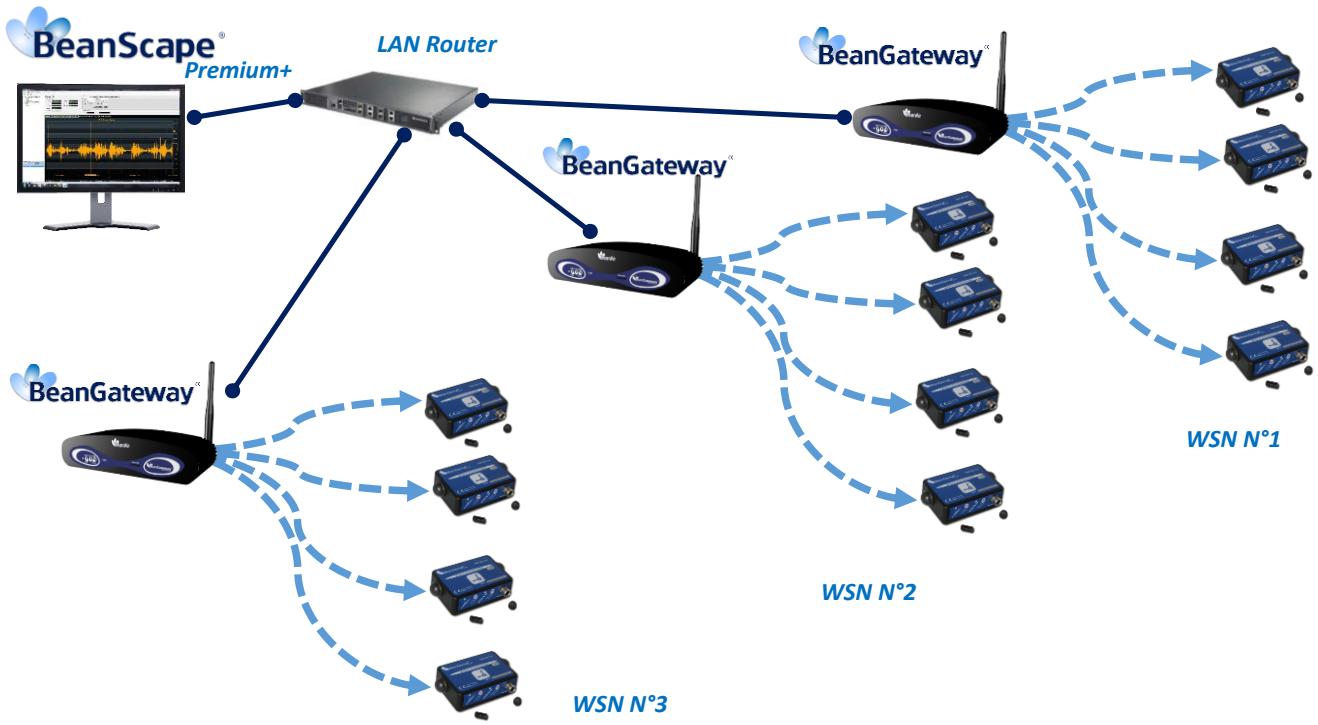

Figure 4: Multi-WSN Architecture

12. OVERALL CONCLUSION

Heterogenous WSN ?	• A combination of different technologies of BeanDevices® does not influence the PER value
	• The number of BeanDevices® influence the global network bandwidth
	• Your environment influence highly the aggregation capacity of WSN:
	  • Antennas characteristics
	  • Antennas orientations
	  • Network area positioning
	  • Network density

BeanGateway® Antenna influence	• Higher is the BeanGateway® antenna's gain, lower is the PER. • If your BeanGateway® is located at the center of your wireless network, an omnidirectional antenna will be recommended. • A directional antenna is highly recommended for extending your wireless range;

13. HOW TO DECREASE DATA LOSS?

13.1 REDUCE SAMPLING RATE

As shown in Section 10, your WSN could be exposed to network saturation as much as your sampling rate is higher. This problem could be multiplied if you are running too much BeanDevices.

Figure 5: Decrease your sampling rate

13.2 USE WSN CONFIGURATION

The architecture described in Section 11 is your best solution when you have too many BeanDevices especially with high sampling rates. In fact, each group of BeanDevices would be using a different radio channel and therefore avoid overloading the network.

13.3 USE "TX & LOG" OR "LOG ONLY"

The BeanDevices integrate an internal Datalogger on which samples could be stores and then downloaded through the BeanGateway.

When operating with the Datalogger, there is no Data transmitted from BeanDevice to BeanGateway. So, the user should not be afraid about any data loss through radio transmission.

In the Tx&Log mode, the Datalogger is enabled at the same with the radio transmission as a backup to store Data when there is an issue with the network such as Network cut or saturation.

For further information about the Datalogger, please read the technical note:

"TN-RF-007-BeanDevice-wireless-sensor-DataLogger-User-Guide"