ZigBee Propagation for Smart Metering Networks

The UK government requires energy suppliers to take all reasonable steps to deploy smart meters in customer residences in Great Britain by 2019, with the mass rollout to start in 2014. ZigBee Smart Energy is a solution to be used in smart metering home area networks (HAN), which will include electric meters, gas meters and in-home displays. In addition to the maturity and popularity of the ZigBee Smart Energy application profile, ZigBee's essential strength is its self-healing mesh networking capability, ensuring robust communications.

In its second Smart Metering Equipment Technical Specification (SMETS2), published for consultation on August 13, 2012, the UK's Department of Energy and Climate Change (DECC) proposed a combination of ZigBee Smart Energy Profile and DLMS (Device Language Message Specification) commands and data between devices in a smart metering HAN, permitting solutions based on 2.4GHz radio and 868MHz radio, acknowledging that 2.4GHz (IEEE 802.15.4) solutions are currently available as part of the ZigBee standard and supported by many manufacturers of consumer equipment and metering equipment. According to SMETS2, DECC's HAN RF propagation trial suggests that 2.4GHz radio is likely to achieve approximately 70 percent coverage of homes in Great Britain without using additional equipment, effectively using ZigBee Smart Energy in a point-to-point or star type network, and not using the mesh networking capabilities of ZigBee. The reason for this is primarily that gas meters in particular cannot rely upon router/repeater equipment that is powered and controlled by the consumer, therefore prone to power failures or tampering. For more details about the DECC SMETS2 publication, visit: http://www.decc.gov.uk/en/content/cms/consultations/smets2cons/smets2cons.aspx.

Many of these early 2.4GHz-based HAN installations will not contain enough mains-powered devices to create a mesh with alternate paths. In many cases, an in-home display or gas meter will need to be able to communicate directly with an electric meter or communications hub. Additional routers would ensure robust communications, but they would add to support and hardware costs and would be prone to power loss and tampering. This challenge highlights a need to examine the point-to-point propagation properties of ZigBee operating in unlicensed radio bands in the 2.4 GHz spectrum. Some developers who have had poor experiences with propagation of other 2.4 GHz solutions may fear that ZigBee will be similarly challenged in homes applications, resulting in communication failures and negatively impacting the consumer experience.

Widespread use of ZigBee Smart Energy in the US smart metering program is of little comfort because US regulations allow devices to transmit at much higher power levels (100 mW/+20 dBm) than in the UK and Europe (10 mW/+10 dBm). It could also be argued that UK housing stock uses different building materials. Yet, numerous ZigBee products are already in use in Europe, mainly in home automation, smart lighting and automatic meter reading markets, and major European manufacturers have been satisfied with the propagation performance of ZigBee. However, published test data has not always been generally available to inform the market.

With the increased interest in smart metering in the UK tempered by the lack of available published material, Silicon Labs has experience with a number of organizations on ZigBee propagation tests. Ember ZigBee technology, now a Silicon Labs offering resulting from its acquisition of Ember Corporation, has been used extensively for these tests, including the Silicon Labs' Ember EM357 ZigBee system-on-chip (SoC), as well as technical information and advice on RF and ZigBee matters.

Silicon Labs' Ember SoC is particularly suitable for this type of testing for two reasons:

- It can support transmission power of +8 dBm and receive sensitivity of -102 dBm, a dynamic link budget of 110 dBm and transmitting close to the EU legal limit of +10 dBm without the expense and power consumption of an external PA or LNA.

- The Silicon Labs' Ember EM357 is a popular solution used in many ZigBee Smart Energy HAN devices in the US and the UK, so it is directly relevant to the market.

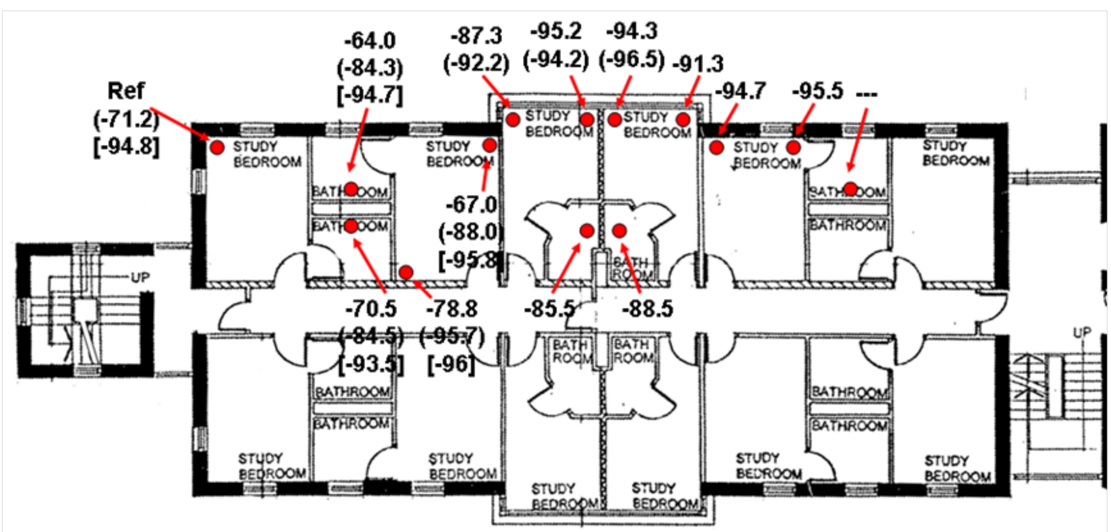
The following two examples show how Silicon Labs' Ember ZigBee technology has successfully supported this type of testing at the University of Sheffield and EDF Energy.

University of Sheffield Tests

The University of Sheffield's Communications Group within the within the Department of Electronic and Electrical Engineering has expertise in radio propagation modeling, active and passive frequency selective surfaces (FSS), antenna systems and wireless systems design. This group has conducted ZigBee propagation tests using Silicon Labs' Ember EM357 SoC. It has published a report that details controlled, scientific tests carried out in a number of reference building types including a terraced house with basement and apartment blocks.

The tests incorporate typical positions of meters and in-home displays. They include a fixed device, usually positioned where a meter would be located such as a basement or at the front door. A second device, which is located at different positions around the building, sends messages to the fixed device. The signals were measured, recording both RSSI (Received Signal Strength Indicator, in dBm) and LQI (Link Quality Indicator, a 0-255 value).

The following figure from University of Sheffield shows results from one of the apartment blocks tested.



Trial 1 – Windows Closed:
Ground Floor
(First Floor)
[Second Floor]

Figure1. Plan of One of the Tests Carried out by the University of Sheffield (Source: University of Sheffield, ZigBee Wireless Quality Trials, 2011, http://www.wfbf.org.uk/publications.html)

The results are very informative, showing the reference device (fixed node) in one corner of the building on the ground floor, and RSSI readings from various positions on ground floor, first floor and second floor.

Table 1. Test Results Related to Figure 1
(Source: University of Sheffield, ZigBee Wireless Quality Trials, 2011, http://www.wfbf.org.uk/publications.html)

Point	Distance (mm)	RSSI (min)	RSSI (avg)	RSSI (max)	LQI
(GROUND FLOOR)					
L3	4225	-64	-64	-64	255
L1	4576	-72	-70.5	-70	255
L2	5661	-80	-78.8	-77	255
L4	7890	-67	-67	-67	255
L5	8147	-88	-87.3	-87	255
L7	10525	-86	-85.5	-85	255
L6	10666	-96	-95.2	-94	80
L8	10984	-96	-94.3	-93	114
L9	12171	-90	-88.5	-88	255
L10	13598	-92	-91.3	-91	252
L11	13670	-96	-94.7	-94	151
L12	16430	-96	-95.5	-95	57
(FIRST FLOOR)					
L0	3230	-72	-71.2	-71	255
L3	5318	-85	-84.3	-84	255
L1	5601	-85	-84.5	-84	255
L2	6518	-96	-95.7	-95	65
L4	8526	-88	-88	-88	255
L5	8764	-93	-92.2	-92	236
L6	11144	-95	-94.2	-93	165
L8	11449	-97	-96.5	-96	18
L7	11009	---	---	---	---
(SECOND FLOOR)					
L0	6460	-97	-94.8	-94	136
L3	7719	-96	-95.7	-95	40
L1	7917	-94	-93.5	-93	209
L2	8589	-96	-96	-96	0
L4	10197	-96	-95.8	-95	2

The RSSI values shed light on how the signal weakens as it goes through internal walls as well as free space. It also indicates the importance of good choice of radio and good PCB design. For example, a test using radios capable of transmitting at +5 dBm with -95 dBm receive sensitivity would represent a 10 dB difference in dynamic link budget and would have negatively impacted these results..

The LQI values are also very interesting. Values of 255 indicate a good quality link, while lesser values indicate the presence of chip errors in the received packets. An LQI of 0 can still result in a successfully received packet, but it is an indication that it would take very little to change in the environment to result in a lost signal.

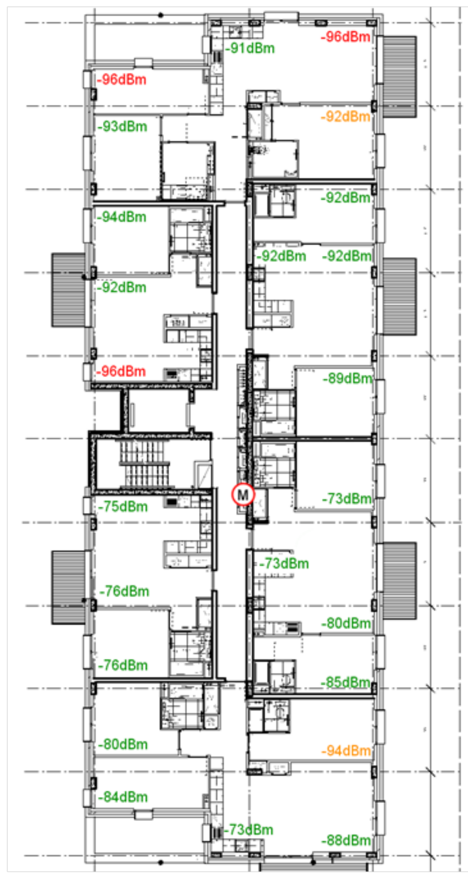
EDF Energy Site Survey

Silicon Labs' Ember technology was used by EDF Energy in testing ZigBee propagation as part of a site survey for a smart metering installation in an apartment block. Silicon Labs' Ember EM357 was used in this site survey, which has subsequently been published by EDF Energy into the SMDG HAN Workgroup working within the Smart Metering Implementation Programme in the UK.

The paper can be found at https://sites.google.com/site/smdghanwg/home/real-world-experiences/EDF2010ZigBeePropagationTesting.pdf?attredirects=0&d=1.

Figure 2 shows a similar pattern to the University of Sheffield tests. In this case the tests are being carried out from a fixed node inside a meter cabinet in the center of one apartment block floor connected to different points in each of six apartments on that same floor.

Location ID	Mean RSSI	Mean LQI	% Packets Received
1	-74.50	255	100
2	-75.89	255	90
3	-76.30	255	100
4	-80.30	255	100
5	-84.00	255	100
6	-72.50	255	100
7	-88.22	251	90
8	-93.57	152	70
9	-85.10	255	100
10	-79.50	255	100
11	-73.30	255	100
12	-72.60	255	100
13	-88.75	247	80
14	-92.00	203	80
15	-92.13	176	80
16	-91.60	189	100
17	-94.40	98	50
18	-96.00	0	20
19	-91.30	220	100
20	-96.00	0	20
21	-93.25	167	80
22	-94.25	110	80
23	-92.00	222	100
24	-95.67	1	30



Packets Received >= 80%
Packets Received >= 50%
Packets Received < 50%

Figure 2. EDF Energy Propagation Tests
(Source: SMDG HAN Work Group https://sites.google.com/site/smdghanwg/home/real-world-experiences/EDF2010ZigBeePropagationTesting.pdf?attredirects=0&d=1)

Summary

With growing interest in using ZigBee for smart metering HANs in the UK and elsewhere around the world, testing propagation properties of these devices at 2.4 GHz is important to advise technology selection, architectural design and deployment plans. Independently conducted tests are becoming available to advise this process, and these tests can only serve to encourage greater understanding of ZigBee propagation in the smart metering community.

These test results, as well as the testing commissioned by DECC, suggest that ZigBee at 2.4 GHz can be a satisfactory solution for smart metering HANs in the majority of homes in the UK, even when the considerable power of ZigBee's mesh networking cannot be used, especially if best-in-class ZigBee radios and robust RF implementations are used.

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