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ZigBee propagation testing for smart metering networks

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The UK Government requires energy suppliers to take all reasonable steps to deploy smart meters at customer residences by 2019, with the mass rollout to start in 2014. ZigBee Smart Energy is a potential solution to be used in smart metering home area networks (HAN), which will include electric meters, gas meters and in-home displays. As well as 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.

However, many of these early HANs will not contain enough mains-powered devices to create a mesh with alternate paths. And 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. This highlights a need to examine the point-to-point propagation properties of ZigBee, which operates in unlicenced radio bands in the 2.4GHz spectrum. Some who have had poor experiences with propagation of other 2.4GHz solutions may fear that ZigBee will be similarly challenged in real homes, resulting in communication failures and negatively impacting the consumer experience.

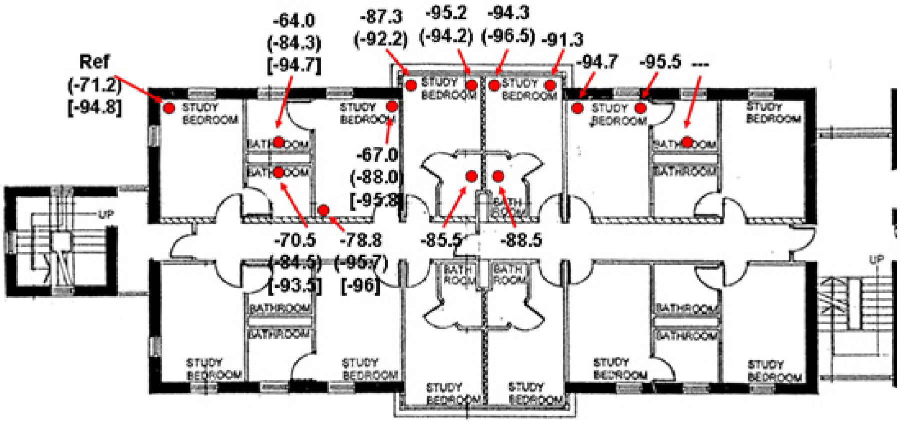
Widespread use of ZigBee Smart Energy in US smart metering programme is of little comfort, because US regulations allow devices to transmit at much higher power levels (100mW/+20dBm) than in the UK and Europe (10mW/+10dBm). It could also be argued that UK housing stock uses different building materials. Yet numerous ZigBee products are already in use in Europe, mainly in home automation or lighting markets, and major European manufacturers have satisfied themselves of the propagation performance of ZigBee. However, no-one has published their test data to inform the market in general.

With the increased interest in smart metering in the UK tempered by the lack of available published material, Ember has worked with a number of organizations to test ZigBee propagation. Ember has provided its ZigBee technology for these tests, including the EM357 ZigBee system-on-chip (SoC), as well as technical information and advice on RF and ZigBee matters.

Ember's SoC is particularly suitable for this type of testing for two reasons;

- It can support transmission power of +8dBm and receive sensitivity of -102dBm, a dynamic link budget of 110dBm and transmitting close to the legal limit of +10dBm without the expense and power consumption of an external PA or LNA; and
- The EM357 is a popular chip used in many ZigBee Smart Energy HAN devices in the US and the UK, so it is directly relevant to the market.

The following are two examples, as well as the results, where Ember has supported this type of testing: the University of Sheffield and EDF Energy.



Trial 1 - Windows Closed, Ground Floor, (First Floor), [Second Floor]

Figure 1: Plan of one of the tests carried out by University of Sheffield (source: University of Sheffield interim report draft, March 2011)

University of Sheffield tests

The University of Sheffield's Communications Group 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 the EM357 SoC and is close to publishing an interim report, which will detail controlled, scientific tests carried out in a number of reference building types, including 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).

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
Point	Distance (mm)	RSSI (min)	RSSI (avg)	RSSI (max)	LQI
(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

Table 1: Table showing test results related to figure 1 (Source: University of Sheffield interim report draft, March 2011).

The figure (on page 16) from University of Sheffield shows results from one of the apartment blocks tested.

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.

The receive signal strength (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 +5dBm with -95dBm receive sensitivity would represent a 10dB difference in dynamic link budget and would have significantly worsened these results. The forthcoming report will contain many more tests like this and should be of great interest to the market.

The LQI values are also very interesting. Values of 255 indicate a good quality link, whilst 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 change that to a lost signal.

EDF Energy site survey

Ember assisted EDF Energy in testing ZigBee propagation as part of a site survey for a smart metering installation in an apartment block. Again, the 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 here: https://sites.google.com/site/ smdghanwg/ home/real-world-experiences/EDF2010 ZigBeePropagationTesting.pdf?attredirects =0&d=1

Figure 3 shows a similar pattern to the University of Sheffield tests. In this case the tests being carried out from a fixed node inside a meter cabinet in the centre of one apartment block floor to different points in each of six apartments on that same floor.

Summary

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

It could be suggested that ZigBee at 2.4GHz is a satisfactory solution for smart metering HANs in the UK based on testing done so far using best in class ZigBee radios and good RF implementations.

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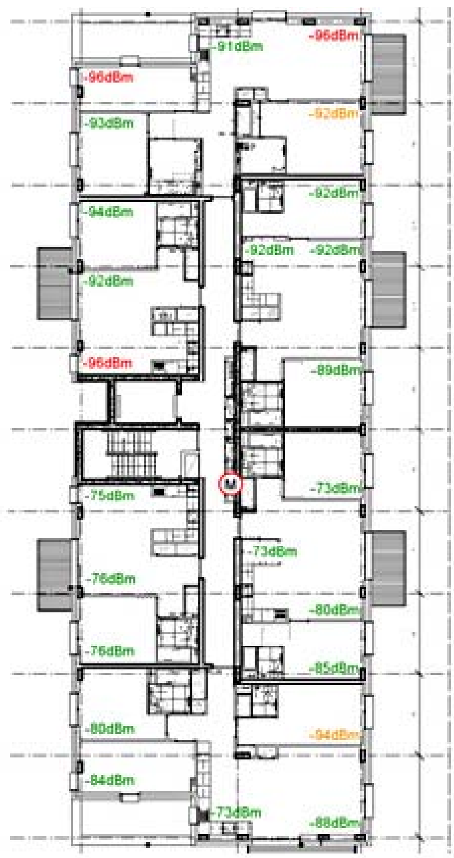

Location ID	Mean RSSI	Mean LQI	% Packets Received
1	-74.50	255	100
2	-75.89	255	90
3	-76.30	255	100
4	-80.30	255	100
5	-84.00	255	100
6	-72.50	255	100
7	-88.22	251	90
8	-93.57	152	70
9	-85.10	255	100
10	-79.50	255	100
11	-73.30	255	100
12	-72.60	255	100
13	-88.75	247	80
14	-92.00	203	80
15	-92.13	176	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

Figure 3: EDF Energy propagation tests (Source: SMDG HAN Work Group https://sites.google.com/site/smdghanwg/home/real-world-experiences/EDF2010ZigBee PropagationTesting.pdf?attredirects=0&d=1)