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Assessment of the feasibility of LoRa IoT sensor node communication link located within a market region

Kufre M. Udofia
Department of Electrical/Electronic and Computer Engineering,
University of Uyo, Nigeria
kmudofia@uniuyo.edu.ng

***Abstract*— In this paper, Assessment of the feasibility of LoRa IoT sensor node communication link within a market region is presented. Notably, Walficsh-Bertoni model is principally applied in estimating the path loss wireless signals can experience within an area that has many building or related obstructions. Along with the Walficsh-Bertoni model, link budget analysis was conducted to determine the link margin and hence the feasibility of wireless communication within the case study market region. Specifically, the study was conducted with different set of data on the transmitter antenna height hb in meters, the height of the buildings HB in meters and the space between the buildings R in meters. The results show that the path loss for the market region with bungalow building increased from a value of 114.2 dB at path length of 1 kn to132.4 dB at path length of 3 km whereas for the 1 storey building market region, the path loss increased from a value of 120.7 dB at path length of 1 kn to138.8 dB at path length of 3 km. Also, the results showed that with a lower transmitter antenna height of 20 m, the path loss is greater and the number of links that are not feasible increases when compared with the one obtained when the antenna height was 40 m. In all, the results show that the antenna height and building height significantly affect the propagation loss in the market region. Also, feasibility of the link decreases with decrease in the transmitter antenna height.**

Keywords— sensor node , Internet of Things, LoRa , communication link, Walficsh-Bertoni Model

1. Introduction

Smart revenue collection system, smart shopping mall application, smart market system and many other smart applications rely on the adoption of Internet of Thing (IoT) sensor networks [1,2,3,4,5,6,7,8,9,10,11,12,13]. Although, there can be wired and fiber optic network that form part of the whole IoT setup, in most cases, the IoT network is mostly wireless network that connects end devices and nodes to the base station or cluster heads from where the data from the nodes or end devices are relayed to the internet server [14,15,16,17, 18,19,20,21, 22,23,24,25, 26, 27, 28,29, 30,31,32]. Particularly, the low-power LoRa transceivers [33,34,35,36] are among the most commonly used technologies for ensuring effective communication between the data capturing devices installed in the market area and the gateway or base station from which the end devices are connected to the internet. The feasibility of the wireless communication in the market region depends on a number of factors [37,38,39,40,41,42,43,44,45,46]. There is the issue of diffraction loss and also multipath loss in addition to the inevitable propagation loss [48,49,50,51, 52, 53, 54, 55,56, 57,58,59,60,61,62,63,64,65]. In this paper, the focus is on the propagation loss impact on the feasibility of wireless link in the market region. However, in order to effectively determine the propagation loss in the market areas, appropriate propagation loss model is needed [66,67,68,69,70,71,72,73,74,75,76,77,78,79,80].

Generally, during the market operating hours, market areas are in many cases full of high density population of humans, vehicles and materials, some of which are static for a sometime interval, while others are mobile. In essence, there is stochastic variation in the distribution of the obstruction within the market during market operating hours. On the other hand, markets are also known to have rows of buildings that are organised with some averagely uniform separation distance between adjacent rows of buildings. As such, the propagation loss in the market area can be effectively modelled using the Walficsh-Bertoni model [81,82,83,84]. In this case, the human, vehicular and material traffic that are associated with market areas during market operating hours are not considered. Rather, the average height of the buildings and the average separation distance between the rows of building are used in the Walficsh-Bertoni model to evaluate the feasibility of wireless communication link.

In any case, the LoRa transceiver may be able to establish direct satellite communication from the given market location, in which case, the obstruction of the buildings in the market may not affect the propagation loss [85,86]. However, this paper did not consider such LoRa-satellite communication link. Rather, it is the terrestrial LoRa IoT sensor node communication link that is considered. In this case, the rows of buildings in the market are considered; particularly, the impact of the building height and the separation distance between adjacent rows of building on the wireless link feasibility are considered [87,88].

2. Path Loss Characterisation Using Walficsh-Bertoni Model

The Walficsh-Bertoni model is principally applied in estimating the path loss wireless signals can experience within an area that has many building or related obstructions. The path loss estimated using Walfisch-Bertoni model, denoted here as $P_{WB}(dB)$ is computed as follows;

$$P_{WB}(dB) = 89.5 - A + B - C + D \quad (1)$$

$$A = 10\left(\log_{10}\left(\frac{\rho_1 R^{0.9}}{(H_B - h_m)^2}\right)\right) \quad (2)$$

$$B = 21(\log_{10}(f_m)) \quad (3)$$

$$C = 18(\log_{10}(h_b - H_B)) \quad (4)$$

$$D = 38(\log_{10}(d)) \quad (5)$$

Where;

$$\rho_1 = \sqrt{\left(\left(\frac{R}{2}\right)^2 + (H_B - h_m)^2\right)} \quad (6)$$

Where h_b and h_m are the transmitter and mobile device antenna height given in meters; R denotes the space between the buildings and it is expressed in meters; H_B denotes the height of the building and it is expressed in meters, f_m denotes the frequency expressed in MHz; while *d* denotes the communication link path length in Km.

2.2 Analysis of Link budget for LoRa

Generally, in wireless communication link with negligible antenna gains for both transmitter and receiver and with transmitter power given as P_{tx}, when the received power of the signal (denoted as P_{rx}) is determined, the feasibility of communication in the link is evaluated using the communication link operating margin (denoted as CL_{OM}), where;

$$P_{rx} = P_{tx} - \text{Path loss} \quad (7)$$

With the path loss given, according to Walficsh-Bertoni model in Equation 1, then,

$$P_{rx} = P_{tx} - P_{WB}(dB) \quad (8)$$

$$P_{rx} = P_{tx} - (-A + B - C + D) \quad (9)$$

Also,

$$CL_{OM}), = P_{rx} - LoRa_{sens} \quad (10)$$

Where $LoRa_{sens}$ is the LoRa transceiver sensitivity given as;

$$L_{MG} = P_{tx} - Pl_{FSP}(dB) - Pl_W(dB) - S_{LoRa} \quad (9)$$

$$LoRa_{sens} = -174 + 10\log_{10}(BW) + NF + SNR_R \quad (3)$$

Where BW, SNR_R and NF represent the operating bandwidth of the LoRa transceiver, the required minimum signal to noise ratio and the noise figure respectively. The typical values of LoRa transceiver sensitivity for the 3 different operating bandwidth values are as shown in Table 1.

Table 1 The typical values of LoRa transceiver sensitivity for the 3 different operating bandwidth values

Spreading Factor, SF	Receiver Sensitivity (dB) for BW of 125 KHz	Receiver Sensitivity (dB) for BW of 250 KHz	Receiver Sensitivity (dB) for BW of 500 KHz
7	-124	-122	-116
8	-127	-125	-119
9	-130	-128	-122
10	-133	-130	-125
11	-135	-132	-128
12	-137	-135	-129

3. Results and Discussion

The parameter values used for the study are:868 MHz and $h_m = 1.5\,m$. The study is conducted with different set of data on the transmitter antenna height hb in meters, the height of the buildings HB in meters and the space between the buildings R in meters. Specifically, for a given hb, Hb and R dataset, the path length d is varied and the results of the path loss based on the Walficsh-Bertoni model is obtained for the different values of d, as shown in Table 2.Specifically, Table 2 shows the results of Walficsh-Bertoni model computed path loss for the market region with hb =40 m and R = 6 m conducted for a bungalow with HB = 3 m and for a storey building with HB =5 m. The results show that the path loss for the market region with bungalow building increased from a value of 114.2 dB at path length of 1 kn to132.4 dB at path length of 3 km whereas for the 1 storey building market region, the path loss increased from a value of 120.7 dB at path length of 1 kn to138.8 dB at path length of 3 km.

Table 2 The results Walficsh-Bertoni model computed path loss for the market region with hb =40 m and R = 6 m conducted for a bungalow with HB = 3 m and for a storey building with HB = 5 m

Link Parameter Configuration S/N	hb (m)	HB (m)	R (m)	d (km)	$P_{WB}(dB)$	Type of building
1	40	3	6	1	114.2	Bungalow
2	40	3	6	2	125.7	Bungalow
3	40	3	6	3	132.4	Bungalow
4	40	5	6	1	120.7	1 Storey
5	40	5	6	2	132.1	1 Storey
6	40	5	6	3	138.8	1 Storey

The feasibility analysis results for the Link Parameter Configuration number 1, where hb =40 m , R = 6 m , HB = 3m and d =1 km is shown in Table 3. The results showed that with the given Link Parameter Configuration 1, the link is feasible for all the LoRa spreading factors operating in the three different bandwidths of 125 KHs, 250 KHz and 500KHz.

Similarly, the feasibility analysis results for the Link Parameter Configuration number 3, where hb =40 m , R = 6 m , HB = 3m and d =3 km is shown in Table 4. The results showed that with the given Link Parameter Configuration 3, the link is feasible for all the 6 LoRa spreading factors operating at bandwidths of 125 KHs, is feasible for 5 out of the 6 LoRa spreading factors operating at bandwidths of 250 KHs, and is feasible for 3 out of the 6 LoRa spreading factors operating at bandwidths of 500 KHs.

Table 3 The feasibility analysis results for the Link Parameter Configuration number 1, where hb =40 m , R = 6 m , HB = 3m and d =1 km

Spreading Factor, SF	Prx (dB) for BW of 125 KHz	LINK MARGIN (dB) for BW of 125 KHz	Link Status for BW of 125 KHz	Prx (dB) for BW of 250 KHz	LINK MARGIN (dB) for BW of 250 KHz	Link Status for BW of 250 KHz	Prx (dB) for BW of 500 KHz	LINK MARGIN (dB) for BW of 500 KHz	Link Status for BW of 500 KHz
7	-104.2	19.8	Feasible	-104.2	17.8	Feasible	-104.2	11.8	Feasible
8	-104.2	22.8	Feasible	-104.2	20.8	Feasible	-104.2	14.8	Feasible
9	-104.2	25.8	Feasible	-104.2	23.8	Feasible	-104.2	17.8	Feasible
10	-104.2	28.8	Feasible	-104.2	25.8	Feasible	-104.2	20.8	Feasible
11	-104.2	30.8	Feasible	-104.2	27.8	Feasible	-104.2	23.8	Feasible
12	-104.2	32.8	Feasible	-104.2	30.8	Feasible	-104.2	24.8	Feasible
		Total No. Feasible	6		Total No. Feasible	6		Total No. Feasible	6
		Total No. Not Feasible	0		Total No. Not Feasible	0		Total No. Not Feasible	0

Table 4 The feasibility analysis results for the Link Parameter Configuration number 3, where hb =40 m , R = 6 m , HB = 3m and d =3 km.

Spreading Factor, SF	Prx (dB) for BW of 125 KHz	LINK MARGIN (dB) for BW of 125 KHz	Link Status for BW of 125 KHz	Prx (dB) for BW of 250 KHz	LINK MARGIN (dB) for BW of 250 KHz	Link Status for BW of 250 KHz	Prx (dB) for BW of 500 KHz	LINK MARGIN (dB) for BW of 500 KHz	Link Status for BW of 500 KHz
7	-122.4	1.6	Feasible	-122.4	-0.4	Not Feasible	-122.4	-6.4	Not Feasible
8	-122.4	4.6	Feasible	-122.4	2.6	Feasible	-122.4	-3.4	Not Feasible
9	-122.4	7.6	Feasible	-122.4	5.6	Feasible	-122.4	-0.4	Not Feasible
10	-122.4	10.6	Feasible	-122.4	7.6	Feasible	-122.4	2.6	Feasible
11	-122.4	12.6	Feasible	-122.4	9.6	Feasible	-122.4	5.6	Feasible
12	-122.4	14.6	Feasible	-122.4	12.6	Feasible	-122.4	6.6	Feasible
		Total No. Feasible	6		Total No. Feasible	5		Total No. Feasible	3
		Total No. Not Feasible	0		Total No. Not Feasible	1		Total No. Not Feasible	3

In addition, the summary of the feasibility analysis results for the Link Parameter Configuration number 1 to 6 are shown in Table 5. The results show that the storey building market areas presented greater path loss and hence the links are not feasible in more cases with the market region that are filled with storey building.

Similar feasibility analysis was conducted with a lower transmitter antenna height of 20 m and the summary of the feasibility analysis results are presented in Table 6. The results showed that with the lower transmitter antenna height, the path loss is greater and the number of links that are not feasible increases when compared with the one obtained when the antenna height was 40 m. In all, the results show that the antenna height and building height significantly affect the propagation loss in the market region.

Table 5 The summary of the feasibility analysis results for the Link Parameter Configuration number 1 to 6

Link Parameter Configuration S/N	Building Type	Total No. Feasible for BW of 125 KHz	Total No. Not Feasible for BW of 125 KHz	Total No. Feasible for BW of 250 KHz	Total No. Not Feasible for BW of 250KHz	Total No. Feasible for BW of 500 KHz	Total No. Not Feasible for BW of 500 KHz
1	Bungalow	6	0	6.0	0	6.0	0.0
2	Bungalow	6	0	6.0	0	6.0	0.0
3	Bungalow	6	0	5.0	1	3.0	3.0
4	1 Storey	6	0	6.0	0	6.0	0.0
5	1 Storey	6	0	5.0	1	3.0	3.0
6	1 Storey	4	2	3.0	3	1.0	5.0

Table 6 The summary of the feasibility analysis results for the Link Parameter Configuration number 1 to 6 where hb =20 m , R = 6 m , HB = 3m and d =3 km.

Link Parameter Configuration S/N	0	Total No. Feasible for BW of 125 KHz	Total No. Not Feasible for BW of 125 KHz	Total No. Feasible for BW of 250 KHz	Total No. Not Feasible for BW of 250KHz	Total No. Feasible for BW of 500 KHz	Total No. Not Feasible for BW of 500 KHz
1	Bungalow	6	1	6.0	0	6.0	0.0
2	Bungalow	5	1	4.0	2	2.0	4.0
3	Bungalow	2	4	1.0	5	0.0	6.0
4	1 Storey	6	3	6.0	0	4.0	2.0
5	1 Storey	3	3	1.0	5	0.0	6.0
6	1 Storey	0	6	0.0	6	0.0	6.0

4. Conclusion

A study on the propagation loss in a market region is presented. The propagation loss is determined using the Walficsh-Bertoni model. The impact of transmitter antenna height , path length and building height on the propagation loss and feasibility of the link are analysed. The study considered the link configuration with a bungalow and another configuration with a storey building. The results show that the antenna height and building height significantly affect the propagation loss in the market region. Also, feasibility of the link decreases with decrease in the transmitter antenna height.

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