

Social Spider Algorithm-based Approach for Propagation Model Optimization. Application to Yaounde Town

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Abstract: The propagation models are used to forecast the influences of terrains and artificial environments on path loss. They are the basis of coverage planning. Good models ensure the precision of planning. With the deployment of 4G network worldwide, operators need to plan the coverage of their network efficiently, in order to minimize the cost and improve the quality of service. In this paper, the standard K factors model is taken into account to develop a method for tuning propagation models based on the social spider algorithm. The data is collected on the existing CDMA2000 1X-EVDO rev B network in the city of Yaoundé. The root mean squared error (RMSE) between actual measurements and radio data obtained from the prediction model developed is used to test and validate the technique. The values of the RMSE obtained by the new model and those obtained by the standard model of OKUMURA HATA in urban areas are also compared. Based on RMSE value from the optimized model and OKUMURA HATA, it can be concluded that the new model developed using the social spider algorithm performs better than the OKUMURA HATA model and is more accurate. The new model proposed on Social spider algorithm is more representative of the local environment. This new evolutionary algorithm prove its performance and can be used anywhere to optimize existing propagation models.

Keywords: Social Spider Algorithm, Radio propagation, mobile network, propagation model optimization.

I. INTRODUCTION

The Internet network, especially broadband, has become an essential resource in everyday life. The challenge today is to offer a good quality services in nomadic and mobile situations. Wireless transmission techniques offer suitable solutions that need to be mastered in order to be able to provide an irreproachable quality of service. The transmission medium is the wireless propagation channel in radio communication systems. Its characteristics, which strongly depend on the environment, influence its performance. In the deployment phase, more accurate field prediction models are

needed to optimize cellular networks. These models are obtained by running tests on existing models like Okumura-Hata or COST231- Hata to produce an optimal propagation model that accurately reflects the characteristics of radio propagation in the given environment.

This work is not the first to focus on the optimization of propagation models. Indeed, several people from various backgrounds have already addressed the issue, each tackling a specific aspect of the problem or part of the network. For example, E. Deussom and E. Tonye [1] worked on "New Propagation Model Optimization Approach based on Particles Swarm Optimization Algorithm"; R. Mardeni and K. F. Kwan [2] presented "Optimization of Hata prediction model in suburban area in Malaysia"; Chhaya Dalela, and al [3] who worked on "tuning of Cost231 Hata model for radio wave propagation prediction"; Medeisis and Kajackas [4] presented "On the Use of the Universal Okumura-Hata Propagation Prediction Model in Rural Areas"; Deussom E. and Tonye E. [5] worked on "Propagation model optimization based on Artificial Bee Colony algorithm: Application to Yaoundé town, Cameroon."; Allam Mousa, Yousef Dama and Al [6] in Palestine presented "Optimizing Outdoor Propagation Model based on Measurements for Multiple RF Cell";

Mingjing Yang and al [7] in China have presented "A Linear Least Square Method of Propagation Model Tuning for 3G Radio Network Planning"; Chen, Y.H. and Hsieh, K.L [8] in Taiwan presented "A Dual Least - Square Approach of Tuning Optimal Propagation Model for existing 3G Radio Network".

In this paper, we propose an optimization approach based on the Social Spider Algorithm (SSA optimization) which is based on a proposed K factors model with 6 coefficients [10][11]. The SSA optimization is capable of optimizing more than 2 coefficients (up to 6 coefficients) in

the K factors model compared to other methods like linear regression mostly used by authors worldwide which are limited on the optimization of only 2 parameters. In addition, SSA can output not only one solution but a set of possible solutions, among them the best one is selected as the final one. This paper will be articulated as follows: in section II, the background, experimental details, and the methodology will be presented, followed in section III by the result obtained after the implementation. In section IV we will present the discussion of the result and finally, we will have a conclusion in section V.

II. MATERIAL AND METHODS

A. Propagation environment

In this study, the data is collected from BTS distributed throughout the city of Yaoundé on a CDMA1X EVDO RevB network. To do this, 3 areas have been chosen in the city of Yaoundé in particular: The dense urban area, namely the city center, the urban area, namely Biyem Assi district, the suburban area namely the Ngousso district. Which correspond respectively to areas with high, medium, and low population agglomerations. The table below shows the areas chosen with the BTS concerned.

Table 1 : type of environment

Categories	A	B	C
Urban characteristics	Dense urban	Urban	Suburban
Concerned BTS	Ministere PTT	Biyem-assi	Ngousso

B. Equipment description

- Simplified description of BTS used
BTS involved in our data collection process is HUAWEI Technologies manufactured. The following table shows the specifications of the BTS.

Table 2: BTS characteristics

	BTS3606	DBS3900
BTS types	Indoor BTS	Distributed BTS (Outdoor)
Number of sectors	3	3
Frequency Band	800MHz	800MHz
Downlink frequency	870 MHz - 880 MHz	870 MHz - 880 MHz
Uplink frequency	825 MHz - 835 MHz	825 MHz - 835 MHz
Max power (mono carrier)	20 W	20 W
BTS Total power (dBm)	43 dBm	43 dBm

The BTS engineering parameters are presented in table 3.

Table 3: BTS parameters (1)

BTS name	Antenna height(m)	Mean elevation	Antenna effective height	Antenna gain(dB)	7/8 feeder cable(m)
Ministry PT_800	40	741,82	47,18	15,5	45
Ngousso	25	712,05	28,95	17	0
Biyem-assi	40	709,54	51,46	15,5	45

BTS type	BTS name	Latitude (degree)	Longitude (degree)	BTS altitude(m)
3606	Ministry PT_800	3, 86587	11,5125	749
3900	Ngousso	3,90097	11,5613	716
3606	Biyem-Assi_800	3,83441	11,4854	721

Table 4: BTS parameters (2)

- Other equipment parameters

In order to perform the radio measurements, a vehicle was used, a laptop, a radio measurement software, namely Pilot Pioneer from Dingli communication V6.0, a CDMA-type LG mobile terminal, a GPS terminal, a DC / AC converter to power the laptop during the measurement.

The drive tests done in the area A, B, and C gave the following results.

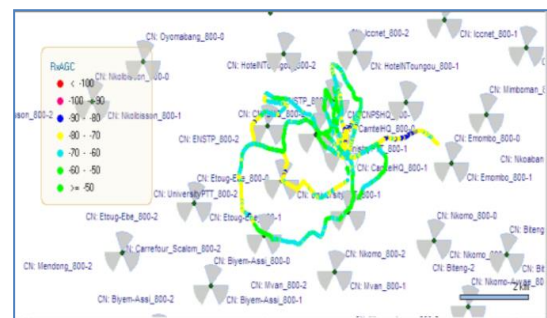


Figure 1: Drive test in center town

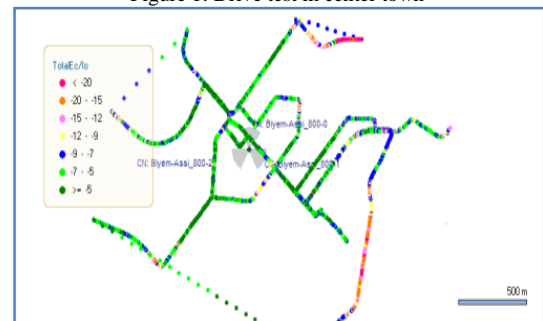


Figure 2: Drive test in Biyem Assi

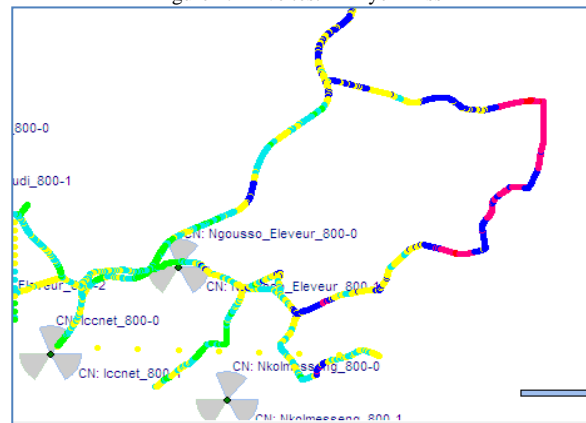


Figure 3: Drive test in Ngousso

C. Methodology

- K factors propagation model [1][12]

There are many propagation models presented in scientific literature, but this modeling is based on K factor propagation model. The General form of the K factors model is given by the following equation:

$$L_p = K_1 + K_2 \log(d) + K_3 \times h_m + K_4 \times \log(h_m) + K_5 \times \log(h_b) + K_6 \times \log(h_b) \log(d) + K_7 \text{diffn} + K_{clutter} \quad (1)$$

K_1 constant related to the frequency, K_2 constant of attenuation of the distance or propagation exponent, K_3 and K_4 are correction factors of mobile phone height; K_5 and K_6 are correction factors of BTS height, K_7 is the diffraction factor, and $K_{clutter}$ the correction factor due to clutter type. The K parameter values vary according to the type of the landscape and the characteristics of the propagation of the city environment;

Equation (1) could also be written in the following form:

$$L_p = (K_1 + K_7 \text{diffn} + K_{clutter}) + K_2 \log(d) + K_3 \times h_m + K_4 \times \log(h_m) + K_5 \times \log(h_b) + K_6 \times \log(h_b) \log(d)$$

Now assuming that $K'_1 = K_1 + K_7 \text{diffn} + K_{clutter}$, equation (1) becomes;

$$L_p = K_1 + K_2 \log(d) + K_3 \times h_m + K_4 \times \log(h_m) + K_5 \times \log(h_b) + K_6 \log(h_b) \log(d) \quad (2)$$

Equation (2) above can be written as follows:

$$L = [K_1 \ K_2 \ K_3 \ K_4 \ K_5 \ K_6] \times \begin{bmatrix} 1 \\ \log(d) \\ H_m \\ \log(H_m) \\ \log(H_{eff}) \\ \log(H_{eff}) * \log(d) \end{bmatrix} \quad (3)$$

In equation (3) only the vector $K = [K_1 \ K_2 \ K_3 \ K_4 \ K_5 \ K_6]$ (4) is a variable.

$$\text{Let } M = \begin{bmatrix} 1 \\ \log(d) \\ H_m \\ \log(H_m) \\ \log(H_{eff}) \\ \log(H_{eff}) * \log(d) \end{bmatrix} \quad (5)$$

Therefore, L can be written in the form:

$$L = K \times M \quad (6)$$

With M a constant vector for a given distance d and depending on if we were under a base station of effective height H_{eff} . If in the contrary the distance d varies for different measurement points, vector M becomes a M_i vector for various measures at different distances points d_i .

- Evaluation function

Here, we have to minimize the Euclidean distance between the measured values of the propagation loss and those predicted by the propagation model. Let $L = \{L_j\}_{j=1:N}$ the set of measured values; where N represents the total number of measurement points of L. K^j is a possible solution vector to our optimization problem and M_i the column vector defined by equation (5). The evaluation function of the particles K^j will be:

$$f_{cost} = \min \left\{ \frac{1}{N} \sum_{i=1}^N (L_i - (K^j \times M_i))^2 \right\} \quad (7)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (L_i - (K^j \times M_i))^2} \quad (8)$$

- Optimization of Propagation model based on the social spider algorithm

The flowchart below represents the determination of the propagation model using the social spider algorithm.

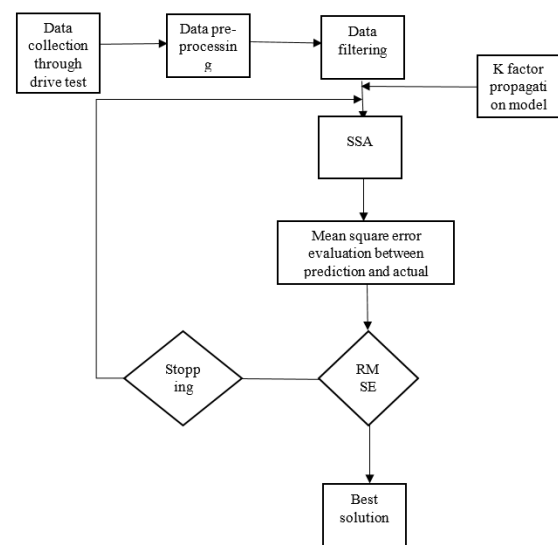


Figure 4: SSA algorithm implementation flowchart

In this chart, data filtering is made according to the criteria of distance and signal strength received:

Table 5: filtering criteria

	Distance (m)	Received power (dB)
Minimum	100	-110
Maximum	10 000	-40

The idea here is to show that using drive test data, the k-factors equation and a suitable social spider algorithm, we can obtain a suitable propagation model for a given frequency. This is illustrated below:

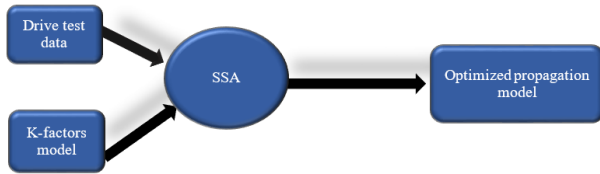


Figure 5: implementation bloc diagram

- SSA Presentation

In SSA we formulate the search space of the optimization problem as a hyper-dimensional spider web [9]. Each position on the web represents a feasible solution to the optimization problem and all feasible solutions to the problem have corresponding positions on this web. The web also serves as the transmission media of the vibrations generated by the spiders. Each spider on the web holds a position and the quality (or fitness) of the solution is based on the objective function, and represented by the potential of finding a food source at the position. The spiders can move freely on the web. However, they cannot leave the web as the positions off the web represent infeasible solutions to the optimization problem. When a spider moves to a new position, it generates a vibration that is propagated over the web. Each vibration holds the information of one spider and other spiders can get the information upon receiving the vibration

1. Vibration

In SSA, we use two properties to define a vibration, namely, the source position and the source intensity of the vibration. we can thus use $I(\mathbf{P}_s, \mathbf{P}_s, t)$ to represent the intensity of the vibration generated by spider s at the source position. This vibration intensity at the source position is correlated with the fitness of its position $f(\mathbf{P}_s)$, and we define the intensity value as follows:

$$I(\mathbf{P}_s, \mathbf{P}_s, t) = \log \left(\frac{1}{f(\mathbf{P}_s) - C} + 1 \right) \quad (9)$$

where C is a confidently small constant such that all possible fitness values are larger than C .

We define the distance between spider a and b as $D(\mathbf{P}_a, \mathbf{P}_b)$ and we use 1-norm (Manhattan distance) to calculate the distance, i.e.,

$$D(\mathbf{P}_a, \mathbf{P}_b) = \|\mathbf{P}_a - \mathbf{P}_b\| \quad (10)$$

2. Search pattern

There are three phases in SSA: initialization, iteration, and final. These three phases are executed sequentially. In each run of SSA, we start with the initialization phase, then perform searching in an iterative manner, and finally terminate the algorithm and output the solutions found.

In the initialization phase, the algorithm defines the objective function and its solution space.

In the iteration phase, a number of iterations are performed by the algorithm. In each iteration, all spiders on the web move to a new position and evaluate their fitness values.

The algorithm then manipulates s to perform a random walk towards V_s^{tar} . Here we utilize a dimension mask m , which is a 0-1 binary vector of length D and D is the dimension of the optimization problem. Initially all values in the mask are zero.

After the dimension mask is determined, a new following position P_s^{fo} is generated based on the mask for s . The value of i -th dimension of the following position $P_{s,i}^{fo}$ is generated as follows:

$$P_{s,i}^{fo} = \begin{cases} P_{s,i}^{tar} & m_{s,i} = 0 \\ P_{s,i}^r & m_{s,i} = 1 \end{cases} \quad (11)$$

where r is a random integer value generated in $[1, |pop|]$, and $m_{s,i}$ stands for the i -th dimension of the dimension mask m of spider s . Here the random number r for two different dimensions with $m_{s,i} = 1$ is generated independently. With the generated P_s^{fo} , s performs a random walk to the position. This random walk is conducted using the following equation:

$$\mathbf{P}_s(t+1) = \mathbf{P}_s + (\mathbf{P}_s - \mathbf{P}_s(t-1)) \times \mathbf{r} + (\mathbf{P}_s^{fo} - \mathbf{P}_s) \odot \mathbf{R} \quad (12)$$

Where \odot denotes element-wise multiplication and \mathbf{R} is a vector of random float-point numbers generated from zero to one uniformly. After this random walk, s stores its movement in the current iteration for the next iteration. This ends the random walk sub-step. The final sub-step of the iteration phase is the constraint handling. The spiders may move out of the web during the random walk step, which causes the constraints of the optimization problem to be violated. The iteration phase loops until the stopping criteria is matched. After the iteration phase, the algorithm outputs the best solution with the best fitness found. The above three phases constitute the complete algorithm of SSA and its pseudocode can be found below. [9]

3. SSA pseudo code [9]

Assign values to the parameters of SSA.

Create the population of spiders pop and assign memory for them.

Initialize V_s^{tar} for each spider.

while stopping criteria not met **do**

for each spider s in pop **do**

Evaluate the fitness value of s .

Generate a vibration at the position of s .

end for

for each spider s in pop **do**

Calculate the intensity of the vibrations V generated by all spiders.

Select the strongest vibration V_s^{best} from V .

if The intensity of V_s^{best} is larger than V_s^{tar} then

Store V_s^{best} as V_s^{tar} .

end if

Update C_s .

Generate a random number r from $[0,1)$.

if $r > P_c^{cs}$ then

Update the dimension mask m_s .

end if

Generate P_s^{fo} .

Perform a random walk.

Address any violated constraints.

end for

end while

Output the best solution found.

4. Generating the initial population

The key point for the implementation of SSA is the coding of every spider and the generation of the initial population, for this work a spider will be a vector with the form of equation (6). The search space is between the standard Okumura-Hata model and the free space propagation model which characterizes a propagation without obstacle. Now let us see how to generate the initial population.

The starting population that is generated is made up of different spiders K^j randomly generated, meeting certain criteria of integrity on the values of the different K_i^j for $i = 1:6$. Let F be the population. Then $F = [K_1^j K_2^j K_3^j K_4^j K_5^j K_6^j]_{j=1:pop}$ [5] [10] [11]

Okumura-Hata model, free space and K factors model propagation model put in the form of equation 16 above will produce the values in the following table:

Table 6: : propagation models into the K factors form.

Propagation model	K_1	K_2	K_3	K_4	K_5	K_6
Okumura-Hata	146.56	44.9	0	0	-	-6.55
Free space	91.28	20	0	0	0	0
K factors	149	44.9	-2.49	0	-13.82	-6.55

The first 3 spiders of our initial population will be those corresponding to the Okumura-Hata model, free space and K factors model of the table above respectively. The other spiders need to be generated in order to complete the size of the population to pop spiders. But before doing that, the criteria that every parameter $K_1 K_2 K_3 K_4 K_5 K_6$ should respect needs to be defined in order to have a solution that fits a real propagation model. The population is generated as follows:

Start

$K1el = 32,4 + 20 \times \log_{10}(Fc)$;

$K1ok = 69,55 + 26,16 \times \log_{10}(Fc)$;

for $i = 1: populationSize$

$K1 = K1el + (K1ok - K1el) \times rand(1)$;

$K3 = -2,49 + 2,49 \times rand(1)$;

$K4 = rand(1)$;

$K5 = -13,82 + 13,82 \times rand(1)$;

$K6 = -6,55 \times rand(1)$;

$K2 = 20 - (K6 \times \log_{10}(Hb)) + ((36,8 - 20) \times rand(1))$;

$P(i, :) = [K1 K2 K3 K4 K5 K6]$;

End for

End;

In this code, $K1ok$ represents the parameter $K1$ in the Okumura-Hata model; $K1el$ represents the parameter $K1$ in the free space model. P is the matrix representing the population generated and the size of the population corresponds to the number of distances measured. This generation of the initial population is based on the initial family generation method made in the work of [11]. The initial population generated is an $N \times 6$ matrix that is N rows and 6 columns. Then value of N corresponds to the number of distances measured and the value 6 represents the 6 parameters of the vector $K = [K1 K2 K3 K4 K5 K6]$. [5] [11] Once the spider population is generated, the SSA is implemented with the different steps explained previously.

III. RESULTS

After the implementation of SSA on the radio measurement data obtained in Yaoundé through drive tests and by setting the parameters as follows: $NS = 100$; the maximum number of iterations is set to 50; The model will be seen as accurate if the RMSE between drive test data and the predicted ones is less than 8 dB; ($RMSE < 8dB$) [5].

We obtained different results represented by curves for each area, the black represents the real propagation, the blue represents Okumura-Hata propagation, the yellow represents the free space propagation and the green represents the SSA.

A. Area A: Center town Yaounde

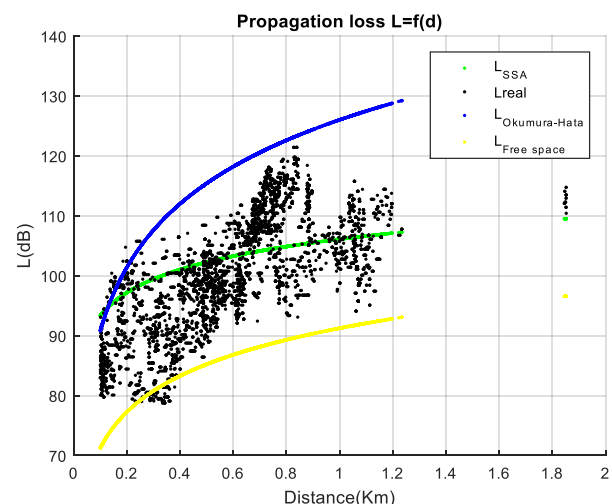


Figure 1: Center town

The table below shows a comparison of the value of the root mean square error for each of the models considered on the curve for the center town case.

Table 7: results from center town Yaoundé

Area	results	K1	K2	K3	K4	K5	K6	RMSE
A	SSA	107.99	22.35	0.0025	0	-	-	6.71
	Okumura-Hata	146.56	44.9	0	0	-	-	16.977
	Free-space	91.28	44.9	-2.49	0	-	-	16.46

We notice that we have a RMSE <8 dB for the new model which confirms the reliability of the result.

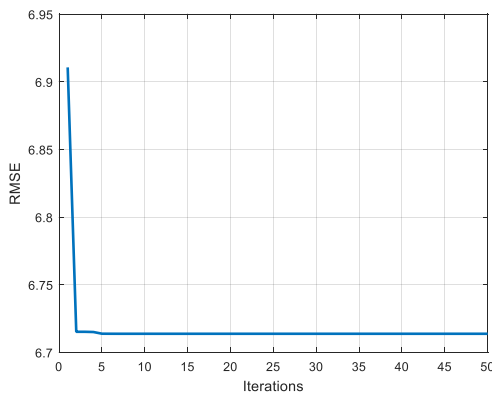


Figure 2: evolution of the Cost function with respect to the number of iterations in the Center town Yaoundé

B. Area B: Biyem Assi district

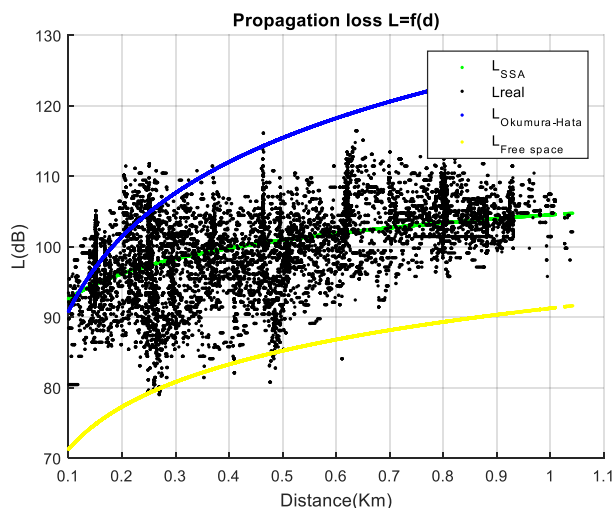


Figure 3: Biyem Assi district

The table below shows a comparison of the value of the root mean square error for each of the models considered on the curve for the Biyem Assi area.

Table 8: results from the Biyem Assi district

Area	results	K1	K2	K3	K4	K5	K6	RMSE
B	SSA	98.88	22.19	0	0	-	-	5.38
	Okumura-Hata	146.56	44.9	0	0	-	-	20.7
	Free-space	91.28	44.9	-2.49	0	-	-	14.85

We notice that we have a RMSE <8 dB for the new model which confirms the reliability of the result.

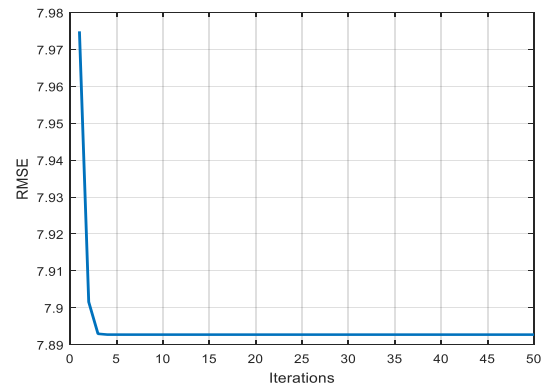


Figure 4: evolution of the Cost function with respect to the number of iterations in the Biyem Assi district

C. Area C: Ngousso district

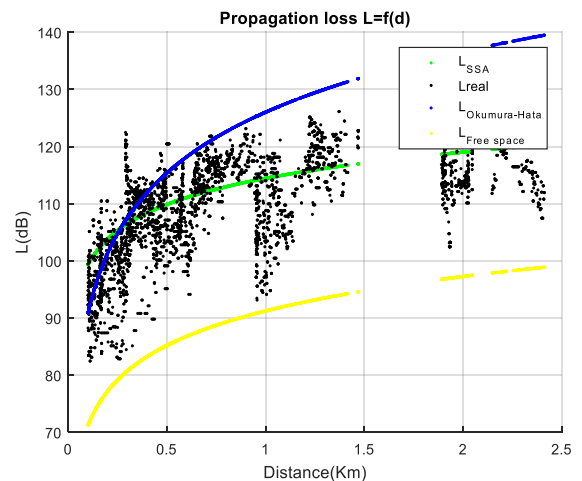


Figure 5: Ngousso district

The table below shows a comparison of the value of the root mean square error for each of the models considered on the curve for the area.

Table 9: results from the Ngousso district

Area	results	K1	K2	K3	K4	K5	K6	RMSE
C	SSA	105.35	30.5	0.036	0	-	-	7.89
	Okumura-Hata	146.56	44.9	0	0	-	-	20.7
	Free-space	91.28	44.9	-2.49	0	-	-	14.85

We notice that we have a RMSE <8 dB for the new model which confirms the reliability of the result.

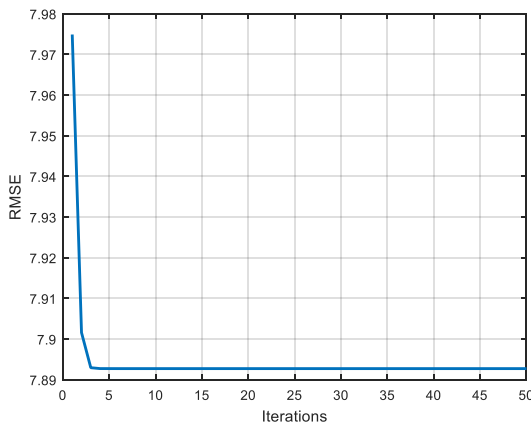


Figure 6: evolution of the Cost function with respect to the number of iterations in the Nguosso district

IV. DISCUSSION

After the implementation of the SSA using the drive tests data from different areas in Yaoundé, we obtain a new propagation model derived from K factors model with 6 coefficients with a RMSE which is less than 8dB. This means that the new model is accurate according to [12].

During this implementation, and at different iterations, some parameter values go out of their specific range and later come back in range after further iterations. furthermore, for all the cases we got a fast convergence of the algorithm after less than 10 iterations while running the algorithm for sometimes 100 iterations. Another detail is that, when running the algorithm several times you can obtain different but accurate results with the same value of RMSE. This is explained by the fact the function rand() outputs values randomly within a specific range, we think it is a drawback of this algorithm. However, we got accurate results when running the Social Spider Algorithm.

The final expression of the propagation model we propose for Yaoundé is thus:

$$L = 97.1997 + 25.014 * \log(d) + 0.0326 * H_m - 13.82 * \log(H_b) - 6.55 * \log(d) * \log(H_b)$$

V. CONCLUSION

This paper presents a new method of optimization of propagation models in a given environment based on a newly

proposed optimization scheme known as Social Spider Algorithm. The set-out method is original and could be used to design or calibrate propagation models. As an advantage, we can get a set of solutions after using SSA and amongst them, we select the best one (with minimum RMSE). However, we found a very fast convergence of the algorithm while we were expecting it to happen after a big number of iterations. Practical measurements done in the city of Yaoundé gave us very good results with an RMSE less than 8dB for most of the selected areas in the city, compared to Okumura Hata RMSE obtained, the new model gives a better result.

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