Explain the effect of Pico Cells and Femto Cells to reduce the Predicted Path Loss of the Mobile Communications

بيان تأثير خلايا Pico و Femto في التقليل من فقدان المسار المتوقع للاتصالات النقالة

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Abstract

Pico cells are a small wireless communication base station covering a small area, often used to extend cellular network coverage to indoor or outdoor areas where signals can not easily penetrate, and also to improve data transfer throughput for mobile users and increase capacity in the mobile network.

Femto cells are a small cellular, low-power wireless access points, typically designed for use in a home or small business. Femto cells deliver significantly improved coverage inside homes, small offices, and outdoor public spaces. This means a stronger signal and better voice quality, plus improved data download and upload speeds.

The aim of this paper is to explain the effect of pico cells and femto cells to reduce the predicted path loss, this achieved by taking a different scenarios and using a MATLAB 2008a programming language to compare the obtained results.

From the results obtained, once can see the importance of using this type of cells to improve the signal quality of the mobile phone.

Keywords: Pico cells, Femto cells Indoor coverage, IP address, Correction factor for mobile unit antenna height ($A(h_r)$), Predicted Path Loss (L_{dB}).

الملخص:

Pico cells هي خلايا صغيرة للاتصالات اللاسلكية تغطي مساحة صغيرة .غالبا ما تستخدم لتوسيع نطاق تغطية الشبكة الخلوية في المناطق المغلقة أو المفتوحة والتي يصعب فيه تخلخل الاشارات، وكذلك لتحسين جودة نقل البيانات لمستخدمي الهاتف النقال وزيادة السعة في شبكة الهاتف النقال.

Femto cell هي محطة لاسلكية خلوية صغيرة وذات طاقة منخفضة, عادة ما تستخدام في المنازل أو المكاتب الصغيرة . Femto cellsتعمل على تحسن التغطية بشكل ملحوظ داخل المنازل والمكاتب الصغيرة ، والأماكن الخارجية العامة. وهذا يعني إشارة أقوى وجودة صوت أفضل، بالإضافة إلى تحسين سرعة تحميل ونقل البيانات.

ألغرض من هذا البحث هو بيان تأثير خلايا pico و femto في ألتقليل من فقدان المسار المتوقع وقد تم ذلك من خلال اتخاذ سيناريوهات مختلفة وأستخدام لغة البرمجة (MATLAB 2008) لمقارنة النتائج التي تم الحصول عليها, حيث بينت النتائج أهمية أستخدام هذا النوع من الخلايا في تحسين نوعية وجودة الاشارة للهاتف النقال.

INTRODUCTION

Picocell and femtocell are tiny, low power base stations that plug into an IP connection to provide a mobile signal directly inside offices and other buildings, often used to extend cellular network coverage to indoor or outdoor areas where signals cannot easily penetrate, and also to improve data throughput for mobile users and increase capacity in the mobile network [1, 2].

Picocell is a small base station that generates a GSM signal in which mobile phone can use without having to transmit through the walls of building. The phone calls and data are carried back to the mobile network over a standard broadband connection, which can be a dedicated DSL (Digital Subscriber line) or the existing high bandwidth office connection [3].

Femtocell is a small cellular, low-power wireless access points, typically designed for use in a home or small business. Femtocells deliver significantly improved coverage inside homes, small and large offices, and outdoor public spaces. This means a stronger signal and better voice quality, plus improved data download and upload speeds.

Femtocells are smaller than microcells and picocells. Picocell and femtocell may not solve every planning challenge – but for getting fast, low-cost coverage and capacity to hard-to-reach places. [2]

Literature survey:

Many researchers have been done on picocells and femtocells. These are some of them; a brief description of some of these researchers is given in the following paragraphs:

1- Mikko Jarvinen, 2009:

"Femtocell Deployment in 3rd Generation Networks";

This thesis studied the femtocell business model, and simulated the performance and co-operation with the macro layer network. It's also study the possible problems in femtocell rollouts and evaluate the status of current standardization and available devices. [4]

2- V. Chandrasekhar, J. Andrews, and A. Gatherer, 2008

"Femtocell networks: a survey";

According to the sequence of received power values from the macrocell user, femtocell user estimates the path loss between itself and the macrocell user by using minimum mean square error (MMSE) method. Simulation results show that the proposed method can efficiently estimate the path loss between any femtocell user and any macrocell user in all kinds of conditions. It's also present overview to the technical and business arguments for femtocells and describes the state of the art on each front. [5]

3- Jeffrey G. Andrews, Holger Claussen, Mischa Dohler, Sundeep Rangan, Mark C. Reed, 2012:

" Femtocells: Past, Present, and Future";

This tutorial article overviews the history of femtocells, demystifies their key aspects, and provides a preview of the next few years, which the authors believe will see a rapid acceleration towards small cell technology. In the course of the article, also position and introduce the articles that headline this special issue. [6]

4- Mardeni.R, Siva Priya.T, 2011

"Performance of Path Loss Model in 4G Wimax Wireless Communication System in 2390 MHz";

This paper outlines how an optimised model for the prediction of path loss for WiIMAX signals up to 2390MHz band is developed. The optimisation is done by determining the difference between the measured and predicted path loss. The optimised model is validated using standard deviation error and relative error analysis [7].

Path loss:

Path loss is the loss of power of an RF signal travelling (propagating) through space. It is expressed in dB. Path loss depends on:

1- The distance between transmitting and receiving antennas.
2- Line of sight clearance between the receiving and transmitting antennas.
3- Antenna height.

Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption.

Path loss includes all of the loss effects associated with distance and the interaction of the propagating wave with the objects in the environment between the antennas. As it shown in figure (1), [8]:

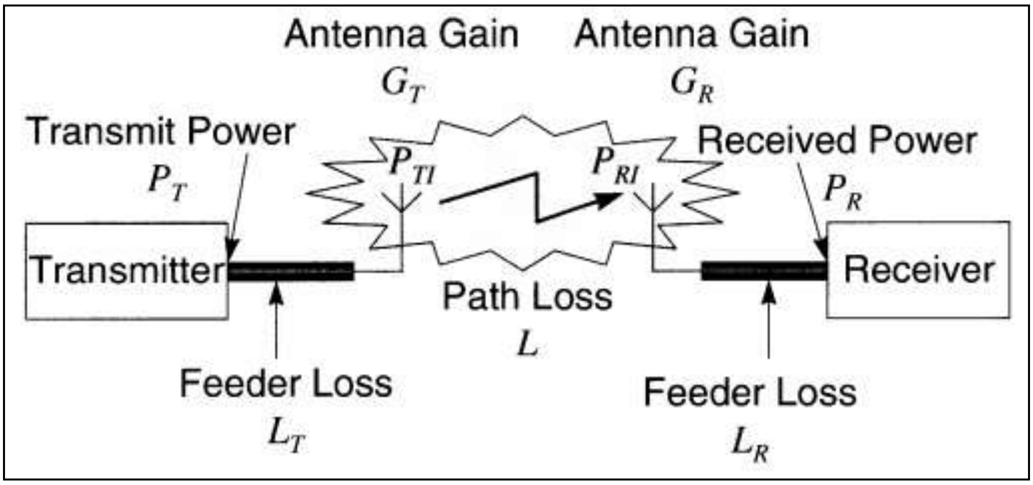


Figure (1): Typical Radio System path loss

In wireless communications, path loss is usually expressed in decibels (dB) as follows [8, 9]:

$$L_{dB} = 10\log_{10}\frac{P_t}{P_r} \tag{1}$$

Where; P_t and P_r are the transmitted and received signal power, respectively.

Predicted Path Loss (L_{dB}):

The accuracy of path loss prediction for large and medium distance can be given as [7, 10]:

$$\mathbf{L_{dB} = 69.55 + (26.16 * \log(f_c)) - (13.82 * \log(h_t)) - A(h_r) + (44.9 - 6.55\log(h_t)) * \log d} \tag{2}$$

And the path loss prediction for small distance (femtocell), can be given as:

$$\mathbf{L_{dB} = 69.55 + (26.16 * \log_{10}(f_c)) - (13.82 * \log_{10}(h_t)) - A(h_r) + (44.9 - 6.55\log_{10}(h_t)) * \log_{10} d - 2[\log_{10}(f_c/28)]^2 - 5.4} \tag{3}$$

Where:

f_c : carrier frequency in (MHz) .

h_t : height of transmitting antenna in (m) .

h_r : height of receiving antenna in (m) .

$A(h_r)$: correction factor for mobile unit antenna height .

d : Propagation distance between antennas in (m).

1-) For a medium(picocell) and small (femtocell) distance between cells, the correction factor is given by [6, 7]:

$$\mathbf{A(h_r) = (1.1 * \log(f_c) - 0.7) * h_r - (1.56 * \log(f_c) - 0.8)} \tag{4}$$

2-) For a large distance between cells , the correction factor is given by the following equation (for $f_c \geq$ 300 MHz) [6, 7]:

$$\mathbf{A(h_r) = 3.2 * (\log(11.7 * h_r))^2 - 4.97} \tag{5}$$

Hence, inorder to explain the effects of picoceel and femtocell on the predicted path loss (L_{dB}), multiple scenarios will be taken, as will be seen in the next subject.

Experimental results:

Figures (2, 3), show the flow charts design procedures to measure the predicted path loss (L_{dB}) of picocell and femtocell respectively.

Figure (2): Flow chart for picocell

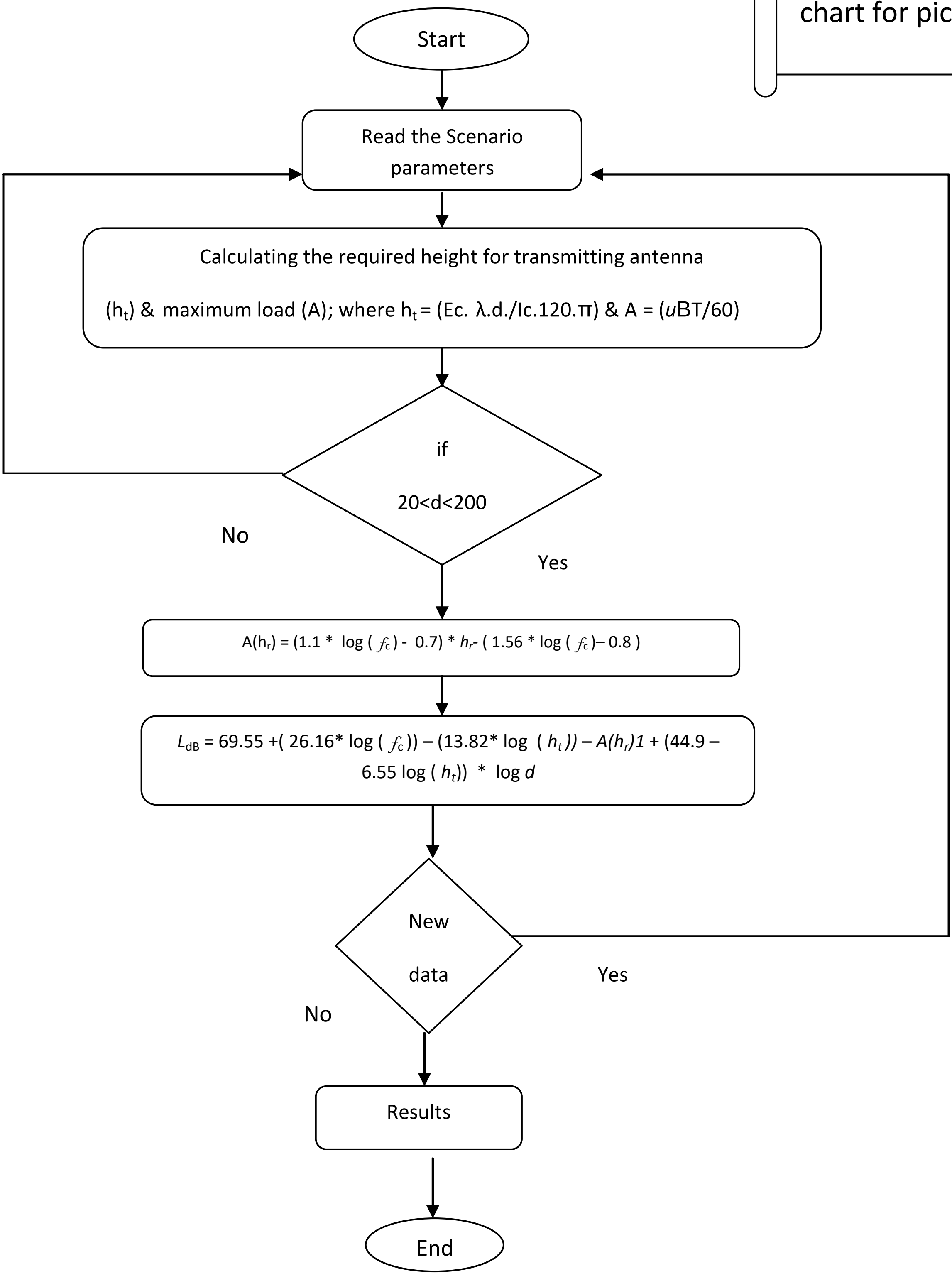
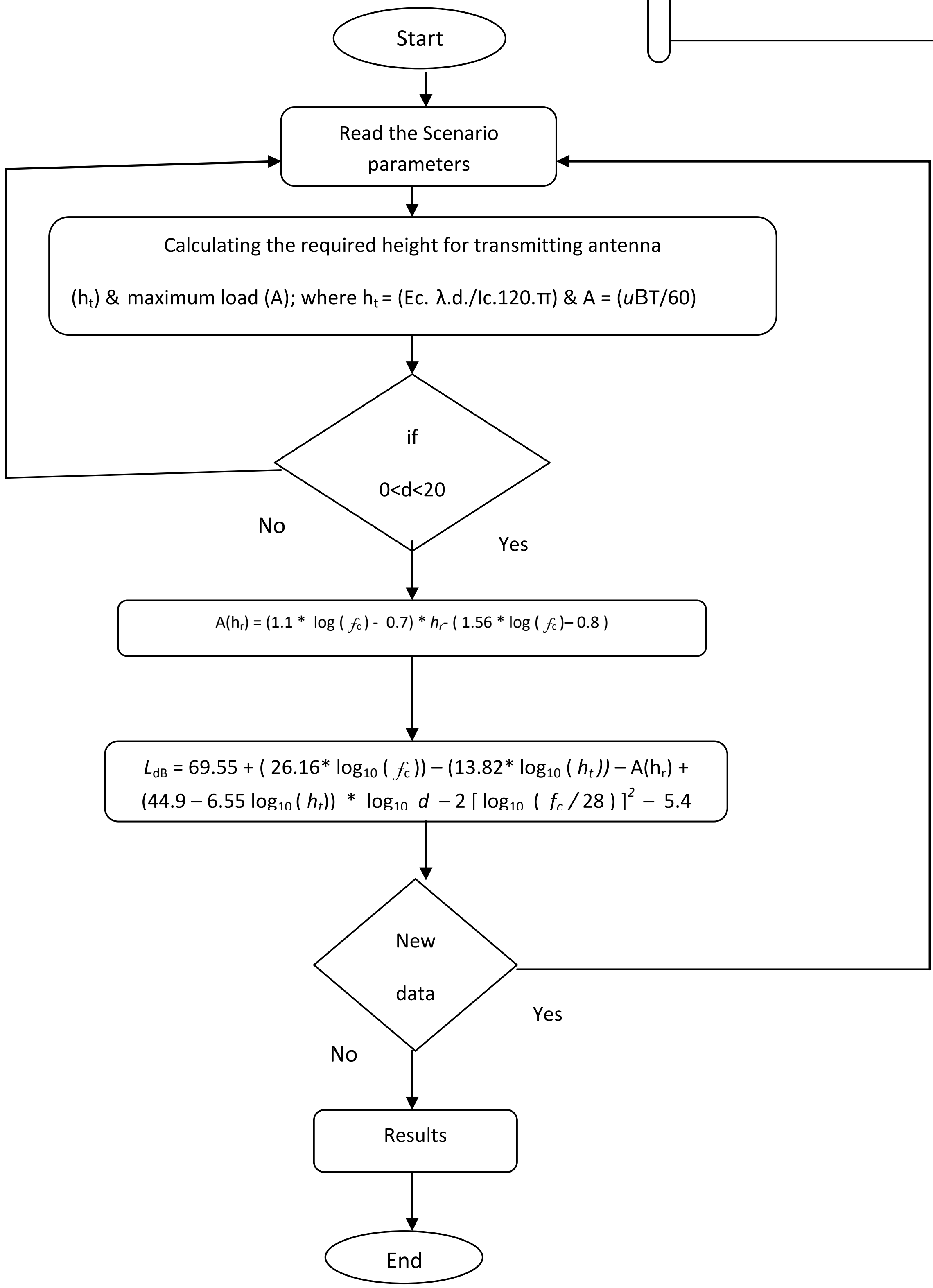


Figure (3): Flow chart for femtocell



Multiple scenarios are taken to illustrate the effects of picoceel and femtocell on the predicted path loss (L_{dB})of, where:
Scenario (I); Table (1) represents the parameters required to estimate the maximum load (A), (which means how many users can share in the network at the same time), transmitting antenna high (h_t), correction factor A(h_r), and the predicted path loss (L_{dB}); for a shopping mall using picocell and femtocell methods.
Scenario (II); Table (2) represents the parameters required to estimate the same values in *Scenario (I),* for a university using picocell method and femtocell methods.
Scenario (III); Table (3) represents the parameters required to estimate the same values in *Scenario (I),* for a hospital using picocell method and femtocell methods.
Scenario (IV); Table (4) represents the parameters required to estimate the same values in *Scenario (I),* for a company using picocell method and femtocell methods.
Table (5), shows a comparison results for the above different scenarios (using the data in tables (1, 2, 3 and 4)), between the predicted path loss (L_{dB}) of using picocell and femtocell methods, and the predicted path loss (L_{dB}) without using picocell or femtocell methods, takes the same parameters values used in table(1, 2, 3, and 4);except using (E_c = 220 volt , I_c = 3 Ampere and d = 500 meters). Also multiple picocell and femtocell are used in the programs to cover the same distances used.

Table (1): Parameter values for shopping mall using picocell and femtocell methods

Area of mall (m^2)	Calculating the maximum load(A)			Carrier frequency(f_c) (MHz)
2000	U (No.)	B (No./min.)	T (min.)	900
	2000	5	2	
The receiver height (h_r)	Calculating the required height for transmitting antenna (h_t) (m)			
22	E_c (volt)	λ (m)	d (m)	I_c (amp.)
	5	0.3333	100	0.05

Where:
U: the user's number;
B: call requests per min.
T: average calling time.
E_c: cell voltage.
λ :wave length.
I_c: cell current.

Table (2): Parameter values for university using picocell and femtocell methods

Area of university (m^2)	Calculating the maximum load(A)			Carrier frequency(f_c) (MHz)
1800	U (No.)	B (No./min.)	T (min.)	900
	2250	4	1.5	
The receiver height (h_r)	Calculating the required height for transmitting antenna (h_t) (m)			
22.5	E_c (volt)	λ (m)	d (m)	I_c (amp.)
	5	0.3333	120	0.05

Table (3): Parameter values for a hospital using picocell and femtocell methods

Area of hospital (m^2)	Calculating the maximum load(A)				Carrier frequency(f_c) (MHz)
2000	U (No.)	B (No./min.)	T (min.)		900
	2500	6	2.5		
The receiver height (h_r)	Calculating the required height for transmitting antenna (h_t) (m)				
23	E_c (volt)	λ (m)	*d* (m)	I_c (amp.)	
	5	0.3333	150	0.05	

Table (4): Parameter values for a business office using picocell and femtocell methods

Area of Office (m^2)	Calculating the maximum load(A)				Carrier frequency(f_c) (MHz)
2500	U (No.)	B (No./min.)	T (min.)		900
	2750	7	2.25		
The receiver height (h_r)	Calculating the required height for transmitting antenna (h_t) (m)				
24	E_c (volt)	λ (m)	*d* (m)	I_c (amp.)	
	5	0.3333	200	0.05	

Results:

From the results in Table (5), one can show that the predicted path loss (L_{dB}) will be decrease when using the picocell and femtocell methods for all above different scenarios.

Table (5): Comparison results between the predicted path loss (L_{dB}) of using picocell and femtocell methods, and the predicted path loss (L_{dB}) without using picocell or femtocell methods.

Scenarios	Results without using Picocell or femtocell method	Results by using picocell method	Results by using femtocell method
	The predicted path loss L_{dB} (dB)	The predicted path loss L_{dB} (dB)	The predicted path loss L_{dB} (dB)
Scenario(I)	363.7347	184.9879	123.9667
Scenario(II)	363.5837	180.4714	109.3859
Scenario(III)	363.4354	176.0428	97.4798
Scenario(IV)	363.1467	167.1412	82.7581

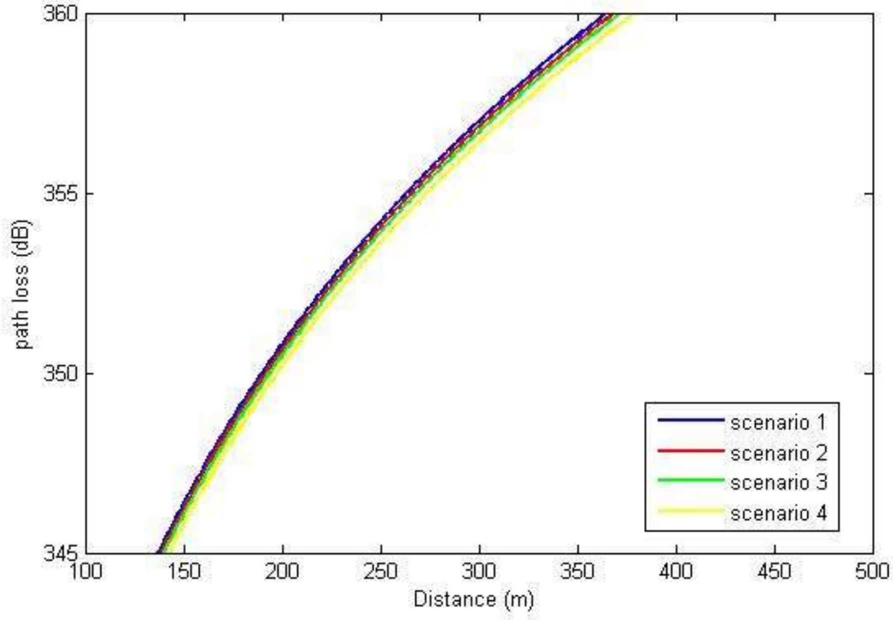


Figure (4): Predicted path loss for repeaters for the four different scenarios.

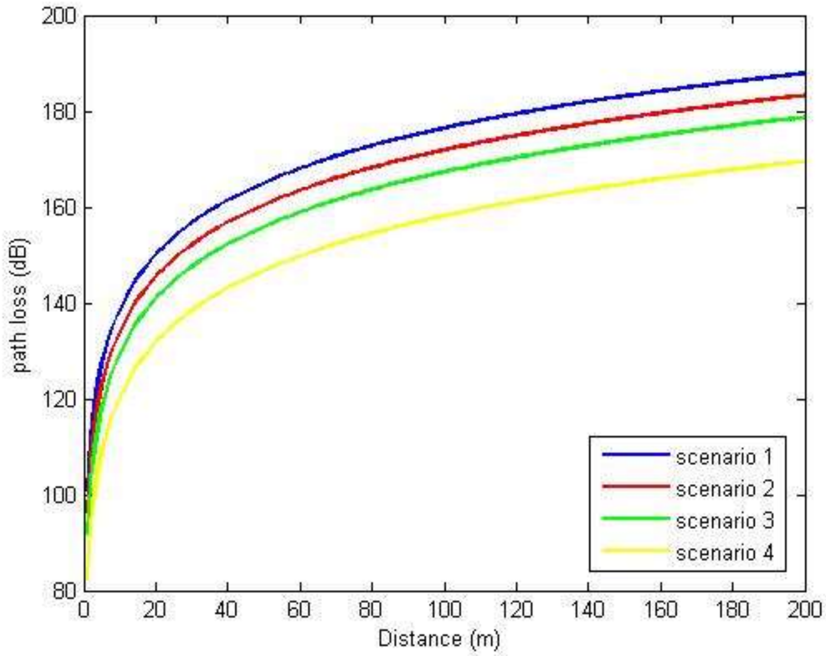


Figure (5): Predicted path loss for picocell for the four different scenarios.

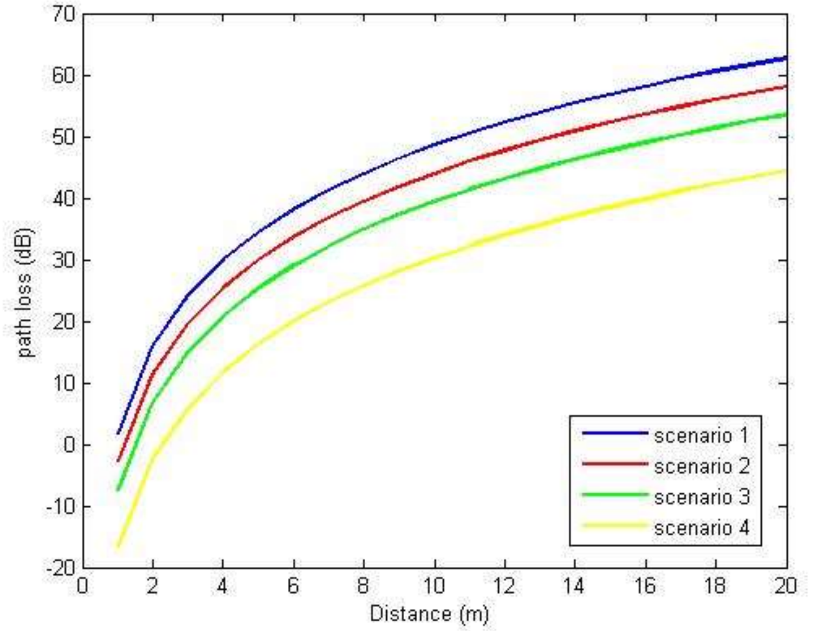


Figure (6): Predicted path loss for femtocell for the four different scenarios.

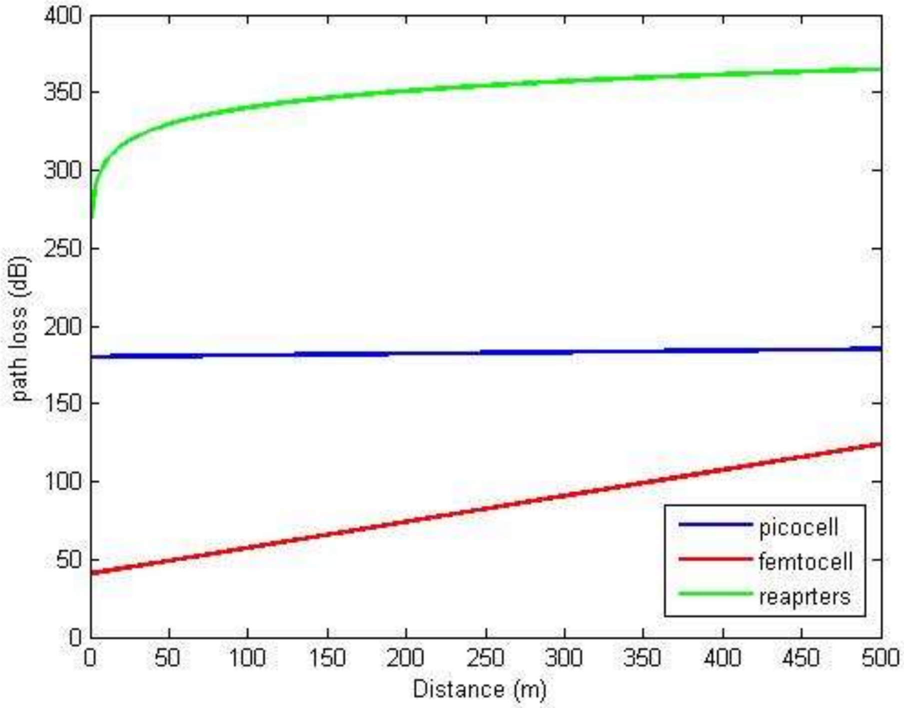


Figure (7): Predicted path loss for the results in Table (5 Scenario 1).

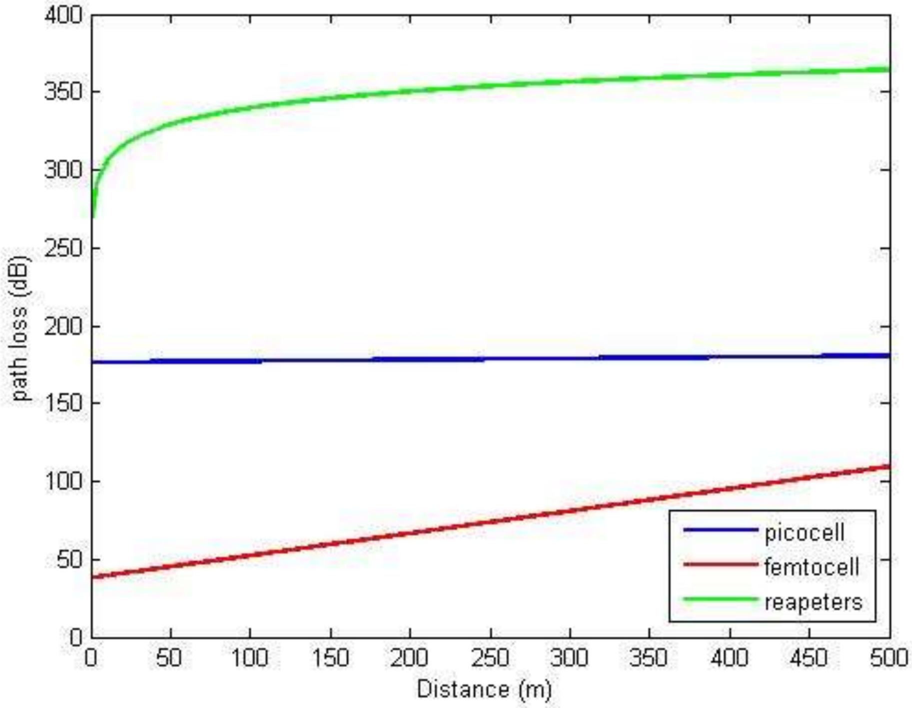


Figure (8): Predicted path loss for the results in Table (5 Scenario 2).

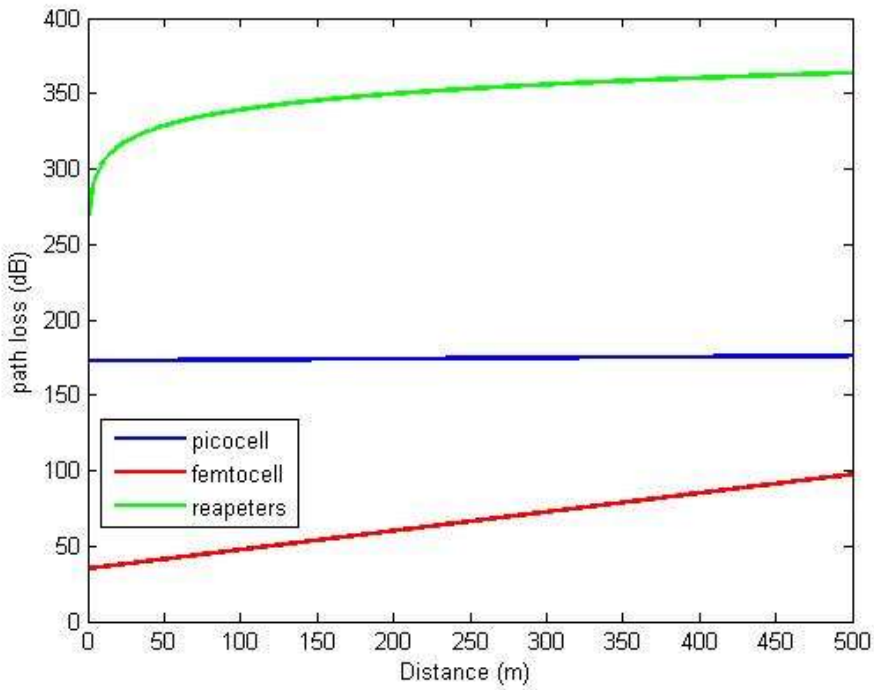


Figure (9): Predicted path loss for the results in Table (5 Scenario 3).

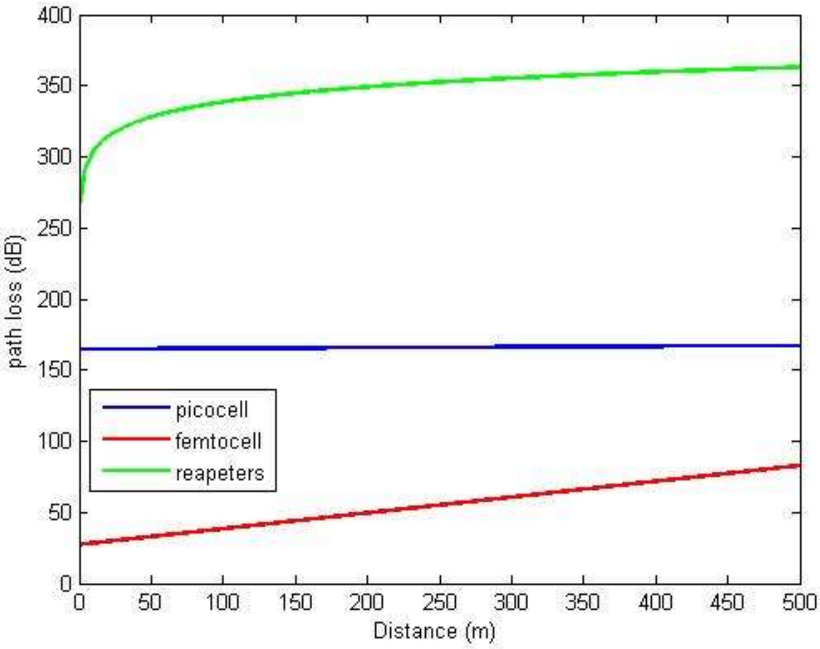


Figure (10): Predicted path loss for the results in Table (5 Scenario 4).

Conclusion:

Picocells and femtocells are small, low- power, low cost and easy of installation indoor base station, they could present mobile operators with an opportunity to make a radical departure from traditional cellular network architecture. From the results in this work, one can conclude that:

1- The results taken from the parameters scenarios (using MATLAB programming) including: shopping mall, university, hospital and a company; show the advantages of using picocells and femtocells compare to the repeaters, as shown in figures (7, 8, 9, 10).

2- From the results in Table (5) and figures (7, 8, 9, and 10), one can show the decrease in the predicted path loss (L_{dB}), that represents the most important factor when using picocells and femtocells, as compare with the results without using these cells for all different scenarios.

3- In addition to the above, one more feature of picocells and femtocell, that it has no health effects on human, because its radiation power is much less than BTS (Base Transceiver station).

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