Signal Quality Improvement for Mobile Phone Using the Pico Cells in Dense Phone Usage Areas

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Abstract

A Pico cell is a small, low-cost, fast coverage and extra capacity which can be used wherever the signal drops. The low cost of these cells and the easy installation as compared with BTSs is very important feature, one more feature is that Pico cells are more effective in dense phone usage areas and at the extremely high buildings, also as its radiation power is much less than BTSs so it has no health effects on human.

This paper makes a design to support the network by using the technique of Pico cells in order to improve the signal quality inside dense phone usage areas and take multiple scenarios to show the importance of using such type of cells. The results show the advantages of using this cell to improve the signal quality especially in dense phone usage areas.

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

تحسين جودة الإشارة للهاتف النقال بأستخدام خلايا PICO CELLS في المناطق الكثيفة أستخدام للهاتف النقال

الخلاصة

خلايا Pico cells هي خلايا صغيرة الحجم وذات تكلفة منخفضة تستخدم كمحطات داخلية في الاماكن التي تكون فيها الاشارة ضعيفة، ان الكلفة المنخفضة وسهولة التركيب لهذه الخلايا مقارنة مع BTSsهي من المميزات المستقبلية المهمة جدا لهذه الخلايا، أضف الى ذلك أن خلايا Pico cells هي أكثر فاعلية داخل الاماكن كثيفة استخدام للهاتف النقال والمباني المرتفعة، كما أن قوة الإشعاع الناتجة من هذه الخلايا هي أقل بكثير مقارنة بمحطات BTSs ولهذا فأن ليس لهذه الخلايا أي آثار تذكر على صحة الانسان.

في هذا البحث تم عمل تصميم لدعم الشبكة باستخدام تقنية خلايا Pico cells من أجل تحسين جودة إلاشارة داخل الاماكن كثيفة استخدام للهاتف النقال حيث تم اتخاذ سيناريوهات متعددة لإظهار أهمية استخدام هذا النوع من الخلايا، وقد أظهرت النتائج أهمية أستخدام هذه الخلايا في تحسين نوعية الاشارة خصوصا في الاماكن كثيفة استخدام للهاتف النقال.

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INTRODUCTION

Pico cell based wireless networks are gaining wide popularity to provide the end user with uniform coverage, symmetry and throughput [1]. A Pico cells are typically used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with very dense phone usage, such as train stations, airports or shopping malls...etc [2].

Every network has black spots where coverage is minimal or non-existent. In areas with marginal coverage, service quality inside buildings can drop off sharply, resulting in call drop, 'network busy' signals, slow data rates and poor voice quality; the traditional solution to in-building coverage problems has been the repeater [3]. But today, planners aren't so quick to turn to repeaters to fill black spots or penetrate buildings, operators originally deployed Pico cells as a "band aid" for coverage in these black spots [4].

Pico cells help to maximize spectrum re-use, provide sufficient extra capacity to ensure that subscribers of premium rate data services get the better radio quality they need, on the other hand Pico cells can provide wireless connectivity to isolated areas like rural places, marine, oil and Gas Company…etc, where there is no broadband connectivity for backhaul, for these circumstances, Pico cells are a viable solution having the satellite communications for backhaul [5].

ESTABLISHING THE CONNECTION

All the Pico cells connected by wires or wireless to a modular unit called the controller which uses IP address to identify the sub network. The unit is connected to external antenna (Omni directional antenna), Pico cells functions (handover, power control....etc) controlled by its own BSC which is connected to the MSC through the (IP backhaul), which is a connection between the Pico cells Omni directional antenna and the BTS microwave antenna, that means Pico cells will support all available services in the network. Figure (1); illustrates the Pico cells based network [5, 6].

The IP address is an address which gives the identification to the Pico cells connected to the network that will increase the network capacity instead of draining it as routers do. While the backhaul is a typical radio access network (RAN), backhaul network connects cell-site nodes with central-site nodes [7, 8].

PROCEDURES OF DESIGN

There are some important points to be discussed before starting the design:

The maximum load (A)

The CDMA techniques offer several advantages over other multiple access techniques, such as high spectral reuse efficiency, soft handoff, capacity improvements by the use of cell sectorization, and flexibility for multirate services [6].

Three important parameters in calculating maximum load which is average calling time (T), the user's number (u) and average number of call requests per minute (b) [9].

$$A = \frac{u \cdot b \cdot T}{60} \quad \text{…(1)}$$

The number of channels in one cell (C **) [9, 11]:**

$$C = \left(\frac{B_t}{B_{ch}} \right) / K \quad \text{….(2)}$$

Where:

B_t : Total bandwidth.

B_{ch} : Channel bandwidth.

K : Number of cell in cluster.

Transmitted power calculation (P_t **)**

The transmitted power in Pico cell is very small (because its coverage area is small), anywhere the transmitted power depends on the receiving power, propagation distance between antennas, and the total gain of receiving and transmitting antenna which are used by the subscriber [3, 5].

The required height for transmitting antenna (h_t **) [10, 12]:**

$$h_t = \frac{E_c \cdot l \cdot d}{120 \cdot p \cdot I_c} \quad \text{…(3)}$$

Where:

E_c : Cell voltage.

I_c : Cell current.

Bandwidth

From (875-925MHz) a (50MHz); (the bandwidth of the uplink is 25MHZ, and bandwidth of the downlink is 25MHZ), the center frequency (f_c) is 900MHz [2, 8, 10].

Predicted Path Loss (L_{dB} **)**

The accuracy in the path loss prediction can be given as [10];

$$L_{dB} = 69.55 + 26.16 \times \log(f_c) - 13.82 \times \log(h_t) - A(h_r) + (44.9 - 6.55 \log(h_t)) \times \log(d) \quad \text{…(4)}$$

Where:

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.

For a small or medium distance between cells, the correction factor is given by [10]:

$$A(h_r) = (1.1 \times \log(f_c) - 0.7) \times h_r - 1.56 \times \log(f_c) - 0.8 \qquad \dots(5)$$

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

$$A(h_r) = 3.2 \times (\log(11.7 \times h_r)^2 - 4.97 \qquad \dots.(6)$$

EXPERIMENTAL RESULTS

Different scenarios are taken (for the same parameter values) to illustrate the advantages of using the Pico cells, where:

Scenario (I); Table (1) [9, 10, 11, 12], represents the parameters required to estimate the maximum load (A), number of channels in one cell (C), transmitting antenna high (h_t), correction factor $A(h_r)$, and the predicted path loss (L_{dB}); for an airport using Pico cell method.

Scenario (II); Table (2), represents the parameters required to estimate the same values in ***Scenario (I)***, for a train station using Pico cell method.

Scenario (III); Table (3), represents the parameters required to estimate the same values in ***Scenario (I)***, for a shopping mall using Pico cell method.

Scenario (IV); Table (4), represents the parameters required to estimate the same values in ***Scenario (I)***, for a stock exchanges using Pico cell method.

Table (5), show the results for the above different scenarios, using the data in tables (1, 2, 3, and 4) for Pico cell method.

Table (6), show a comparison results between the predicted path loss (L_{dB}) table (5), and the predicted path loss (L_{dB}) without using Pico cell, takes the same parameter values used in tables (1, 2, 3, and 4); except using ($K = 1$, $E_c = 220$ volt, $I_c = 3$ Ampere, and $d = 500$ meter).

DISCUSSION

Two points in the discussion, firstly, discuss the subject of the work with respect to the other. Secondly discuss the results.

Firstly, discuss the feature of our work with other related distinct researches.

In [9, 11], an algorithm to calculate the number of cell in cluster is made, the maximum load, and the number of channels in one cell, in order to increase the performance (in terms of capacity) of a cellular network, but without taking the other effective parameters and different scenarios as done in this work. In [10], a good analysis and calculation are made only for the required height, transmitting antenna, correction factor for mobile unit antenna height, and the accuracy in the path loss prediction, in order to increase the resolution of position detection, without making a comparison for the predicted path loss and without taking different scenarios. While this paper takes all the effective required parameters for different scenarios and makes a comparison between the results of using Pico cells and the results without using Pico cells for the predicted path loss for all different scenarios.

Secondly, different scenarios are taken in this work with different (areas, number of users, number of call requests per min, average calling time, height of receiving antenna, and propagation distance between antennas), from the results one can show that the correction factor $A(h_r)$, and the predicted path loss (L_{dB}) are very sensitive to the changes in the receiving antenna high (h_r), and the propagation distance between antennas (d).

CONCLUSIONS

Pico cells are small, low-cost indoor base stations, 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 in different scenarios (using Matlap programming) including; airport (table (1)), train station (table (2)), shopping mall (table (3)), and stock exchanges (table (4)); show the advantages of using such future type (Pico cells), see table (5).
2) Table (6), show a decrease in the predicted path loss (L_{dB}), which is the most important factor, when using Pico cells comparing with results without using Pico cells for all different scenarios.
3) In addition to the above, one more future of Pico cells, that it has no health effects on human, because its radiation power is much less than BTS.

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Table (1) Parameter values for an airport using Pico cell method.

Area of airport (m^2)	**Area of one cell** (A_c)(m^2)	**Calculating the maximum load (** A **)**			**Calculating the No. Of channels in one cell (** C **)**	
2000	100	u **(No.)**	b **(No./min)**	T **(min.)**	B_t **(MHZ)**	B_{ch} **(KHZ)**
		2000	5	2	40	20

Carrier frequency (f_c) (MHZ)	**The receiver height** (h_r)(m)	**Calculating the required height for transmitting antenna** (h_t) (m)			
900	25	E_c (volt)	l (m)	d (m)	I_c (Amp.)
		5	0.3333	100	0.05

Table (2) Parameter values for train station using Pico cell method.

Area of train station (m^2)	Area of one cell $(A_c)(m^2)$	Calculating the maximum load (A)			Calculating the No. Of channels in one cell (C)	
		u (No.)	b (No./min)	T (min.)	B_t (MHZ)	B_{ch} (KHZ)
1800	90	3000	4	1.5	40	20

Carrier frequency (f_c) (MHZ)	The receiver height $(h_r)(m)$	Calculating the required height for transmitting antenna (h_t) (m)			
		E_c (volt)	l (m)	d (m)	I_c (Amp.)
900	22.5	5	0.3333	90	0.05

Table (3) Parameter values for shopping mall using Pico cell method.

Area of mall (m^2)	Area of one cell $(A_c)(m^2)$	Calculating the maximum load (A)			Calculating the No. Of channels in one cell (C)	
		u (No.)	b (No./min)	T (min.)	B_t (MHZ)	B_{ch} (KHZ)
800	90	2500	6	2.5	40	20

Carrier frequency (f_c) (MHZ)	The receiver height $(h_r)(m)$	Calculating the required height for transmitting antenna (h_t) (m)			
		E_c (volt)	l (m)	d (m)	I_c (Amp.)
900	20	5	0.3333	90	0.05

Table (4) Parameter values for stock exchanges using Pico cell method.

Area of stock exchanges (m^2)	**Area of one cell** $(A_c)(m^2)$	**Calculating the maximum load** (A)			**Calculating the No. Of channels in one cell** (C)	
		u **(No.)**	b **(No./min)**	T **(min.)**	B_t **(MHZ)**	B_{ch} **(KHZ)**
1000	85	2200	7	2.25	40	20
Carrier frequency (f_c) (MHZ)	**The receiver height** $(h_r)(m)$	**Calculating the required height for transmitting antenna** (h_t) (m)				
		E_c (volt)	l (m)	d (m)	I_c (Amp.)	
900	17.5	5	0.3333	85	0.05	

Table (5) Results (in different scenarios), of using the data in tables (1, 2, 3, and 4) for Pico cell method.

Scenarios	**The maximum load** (A)	**The No. Of channels in one cell** (C)	**Transmitting antenna** $(h_t)(m)$	**The correction factor** $A(h_r)$ **(dB)**	**The Predicted path loss** L_{dB} **(dB)**
Scenario (I)	333.3333	100	8.8419	215.5731	152.5389
Scenario (II)	300	100	7.9577	192.6989	174.8603
Scenario (III)	625	225	7.9577	169.8247	197.7345
Scenario (IV)	577.5	170	7.5157	146.9505	220.2973

Table (6) Comparison results between table (5), and the results without using Pico cell method for the predicted path loss.

Scenarios	**Results using Pico cell method**	**Results without using Pico cell method**
	The Predicted path loss L_{dB} (dB)	**The Predicted path loss L_{dB} (dB)**
Scenario (I)	152.5389	362.6743
Scenario (II)	174.8603	363.5837
Scenario (III)	197.7345	364.3684
Scenario (IV)	220.2973	365.2376

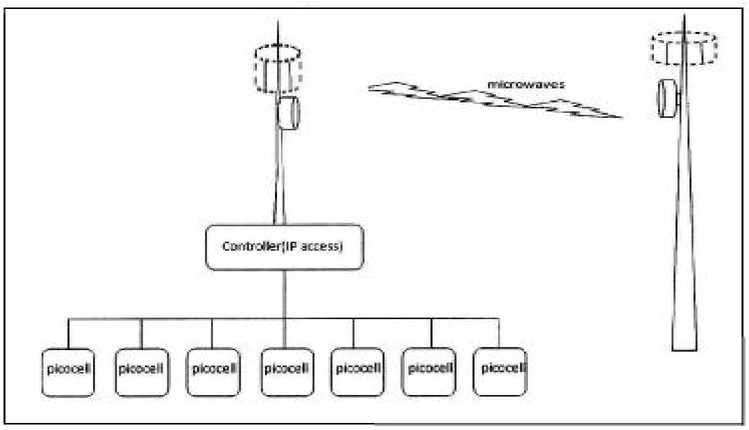

Figure (1) The Pico cells based network.