Integrated Satellite- APs-Terrestrial System for UMTS and LTE Network

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***Abstract*—** In this paper the integrated satellite, Aerial Platform (AP) and terrestrial system, analyses including the effects of cooperative protocols in order to evaluate the system performance. This models supporting more flexible coverage areas and spatial capacity assignments for effective resource utilization and for better performance. It considered a dense urban (at 2600MHz) and sub-urban (at 2100MHz) channel model. The analytical results with Quadrature Phase Shift Keying (QPSK) modulation, validated by simulation, were provided to illustrate the performance with both cooperative diversity and no diversity reception for various received signal. The performance of Long Term Evolution (LTE) and Universal Mobile Telecommunication System (UMTS) system analysis is provided for amplify-and-forward cooperative over integrated model using Cost 231 Hata and Standard Propagation Model (SPM). The results indicate that the proposed system the capacity and coverage are significantly increased and hence it is suitable for intelligent coverage and capacity optimization. In addition to this it can be used for hot-spot areas at planned events, mobility on demand, emergency situations, load balancing, and supporting broadband services at satisfactory quality.

***Keywords*—**Cooperative Protocol, APs, Satellite, UMTS, LTE

I. Introduction

WIRELESS communications technologies have seen a remarkable fast evolution in the past two decades. Each new generation of wireless devices has brought notable improvements in terms of communication reliability, data rates, device sizes, battery life, and network connectivity [14].The network is set to accommodate this in a uniform, hexagonal grid of cells and uniform distribution of users throughout the network. Networks exercise a small portion of their ultimate capacity; however the users' density varies between extremely dense in urban areas to very sparse in rural areas. , BSs (base station) in a business district may be very busy for ten hours a day, but when the business people depart, there is negligible offered traffic [3]. So it needs flexible capacity and coverage system.

Over half of the cells in every major market are coverage-limited, seeking to cover large, sparsely populated areas, while capacity-limited cells in the urban core seek the confinement to a small coverage where the cell's capacity is utilized, and there is isolation from neighbor cells' interference. The topography and land cover - building, forests - limit the coverage of the base transceiver station (BTS) antenna and its uniformity, sometimes creating shadowed areas ("radio holes") within the cell coverage, while shedding excessively strong signals to adjacent cells in other cases. The hexagonal grid is then left as conceptual schematics and has to give way to a detailed architecture planning based on propagation rules, users' densities and air interface dynamics of the relevant system [19]. In addition to the above problem a terrestrial radio link faces a great deal of obstacles in its path: Hence, the electromagnetic wave cannot travel great distances, while a satellite link features an extremely long transmission path (distance may be in the order of hundreds of kilometers for the low-earth orbit satellites) and, which weakens the wave and demands additional cost, although less obstacles obstruct the signal [5, 9]. Other problem is the design of a satellite system is a complicated, difficult task and it takes several years to design different parts of a system to add additional service need [11]. Therefore it is mandatory to clearly understand the potentialities resulting from a synergic integration of earth, space (satellite) and stratospheric segments (Aps platform) to get a flexible system to use the existing resource effectively.

APs usage mitigates multipath effects, typical of terrestrial cellular systems, and decrease geostationary satellite propagation delays. Stratospheric platforms work as simple transponders and all functionalities of control and management are forwarded to the APs Master Control Station (HMCS) that performs resources allocation and traffic management inside a single stratospheric platform coverage area. This novel communication infrastructure has the advantages of higher line of sight capability and wider coverage area compared with the terrestrial systems, and a much shorter propagation distance which therefore give a significant advantage of link budget compared with the satellite systems. They could be self-launched, easily recovered for maintenance, whenever necessary, and moved to cover different regions, if desired and use to balance coverage and capacity requirement [4]. In addition to this for these seniors it can be also uses as a source of transmission a communication signal. Such a communication system consists of a stratospheric platform APS (including airships, communication payloads, additional mission payloads, etc.), user terminals, several gateways, and the ground facilities for TT&C (Telemetry, Tracking, and Command) [6].

The stratospheric platform can obtain high capacity by employing a multi-beam antenna system, incorporating the frequency reuse and their transceivers are co-located on the platform and they offer a line of sight communication to a geographic service area of approximately 60km diameter [2, 7]. Such systems will employ a cellular architecture in order to

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provide overall system capacity, with cells served by a number of antenna spot beams from the Aps [1].

The quasi-stationary aerial platforms operating in the stratosphere preserve many advantages of both terrestrial and satellite systems but also provide special advantages of their own. Mobility on demand, large coverage, payload configurability, capability of frequent take-offs and landings for maintenance and upgrading and very favorable path-loss characteristics (with respect to terrestrial or satellite systems. While it is generally acknowledged that APs for example HAPs could offer a higher spectrally efficiency than GEO satellites. This is based on the assumption that a cellular approach is used with the minimum cell size being limited by the maximum size of the antenna payload that can be accommodated on the HAP [10]. Satellite layer uses GEO regenerative satellites that are provided with On-Board Processing (OBP). It can use forward channel both towards terrestrial layer and APs layer. Terrestrial layer is composed of all user terminals and cooperative each other.

Space or multiple-antenna, diversity techniques are particularly attractive as they can be readily combined with other forms of diversity, e.g., time and frequency diversity, and still offer dramatic performance gains when other forms of diversity are unavailable. In contrast to the more conventional forms of space diversity with physical arrays builds upon the classical relay channel model [5] and examines the problem of creating and exploiting space diversity using a collection of distributed antennas belonging to multiple terminals, each with its own information to transmit. We refer to this form of space diversity as cooperative diversity because the terminals share their antennas and other resources to create a “virtual array” through distributed transmission and signal processing [5, 22, 23]

In a realistic network the traffic characteristics are dynamically changing [26]. Unbalanced traffic conditions can lead to some cells being congested while others are left with spare capacity. Also, terrain variations, network configuration changes and seasonal changes (particularly appearance and diminishment of foliage as seasons change) can cause some cells to inject more interference into other cells than in ideal uniform cell size and uniform propagation conditions [25]. Due to the complexity and expense of optimizing network coverage and capacity manually, particularly as network operations and performance management for data networks such as UMTS and LTE get cumbersome.

Higher capacity with APs is also costly. It represents a power advantage of up to about34dB compared to a LEO satellite, or 66dB compared to a GEO satellite. And compared with terrestrial schemes, a single HAP can offer capacity equivalent to that provided by a large number of separate base-stations [37]

The objective of this study is to propose Satellite-APs and terrestrial integrated model to provide more flexible coverage and capacity for the system. What’s more, the system used to maximize the (usually conflicting goals of) coverage, capacity and the quality of service.

Concerning the integration into the UMTS or LTE standard, different scenarios can be conceived for this study employs AP (example HAPs) as ‘‘back-up’’ base stations for covering areas partially served by terrestrial base stations and at the same time it can be used as relay(i. e as cooperative nodes) when satellite send a source signal(see fig. 1). In addition to this development of 3G terrestrial and satellite components, UMTS will provide backward compatibility with second-generation (2G) mobile networks [12]. This paper investigates the possibility of integrated capacity and coverage of a common cell area in UMTS and LTE systems with and without cooperative diversity techniques.

II. System Model

A multi-user wireless communications system, where the source terminal S (Satellite) and AP communicates with the destination terminal D Through a direct link (h_{sd} and h_{rid}) with SNR and collaborative paths of relays (AP and terrestrial network), is considered in Fig. 1.

In the first phase satellite transmits the signal’s one copy directly to the destination and multiple copies of the same signal toward the M cooperative relays terminal with the same power (i.e. Ps), during this phase the AP also transmits signals intended for the destination in a broadcast manner (since AP use as a relay as well as a source) . While in the second phase of communication, each cooperative relay node amplifies the received signal and sends the scaled version to destination node. In this study we consider Amplify and Forward (AAF), protocol, the received signal is merely amplified and forwarded to the destination [17, 20, 21].

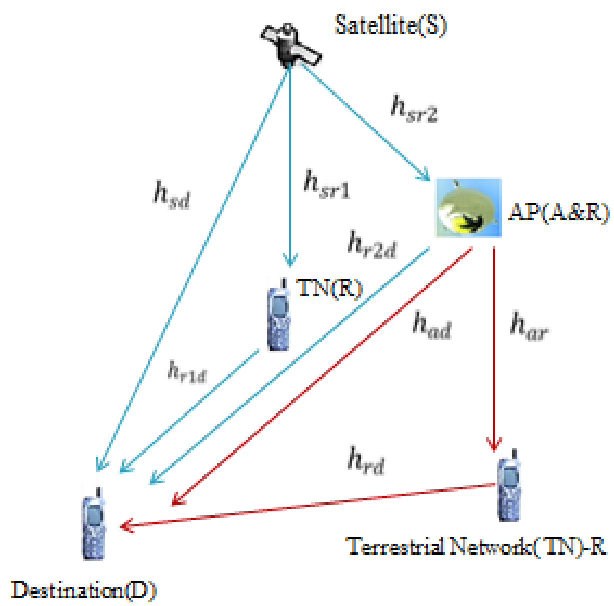

Fig. 1 An integrated satellite, Aerial Platform (AP) and Terrestrial Network

The different received signals at the destination terminal are combined (using MRC combining technique) to achieve a better spatial diversity compared to the one achieved with a single direct path and a single source node. This technique of broadcasting information from different locations makes communication possible even in bad channel conditions. The exact end-to-end SNR of the r th link can be written as [15-18].

$$\gamma_{satellite} = |h_{sd}|^2 \frac{E_s}{N_{sd}} + \sum_{i=1}^{M} \frac{\frac{|h_{sri}|^2 E_s}{N_{sr}} \cdot \frac{|h_{rid}|^2 E_i}{N_{rd}}}{\frac{|h_{sri}|^2 E_s}{N_{sr}} + \frac{|h_{rid}|^2 E_i}{N_{rd}} + 1} \quad (1)$$

$$\gamma_{satellite} = \gamma_{sd} + \sum_{i=1}^{M} \frac{\gamma_{sri} \cdot \gamma_{rid}}{\gamma_{sri} + \cdot \gamma_{rid} + 1} \quad (2)$$

Where, $\gamma_{sri} = \frac{|h_{sri}|^2 E_s}{N_{sr}}$,$\gamma_{rid} = \frac{|h_{rid}|^2 E_i}{N_{rl}}$ and $\gamma_{sri} = |h_{sd}|^2 \frac{E_s}{N_{sd}}$ are the instantaneous signal-to-noise ratio (SNR), between satellite and cooperative terminal, cooperative terminal and destination terminal, and satellite system and destination terminal respectively [13, 24]

Assuming all cooperative terminal have same characteristics and substitute $\gamma_{sd} = \gamma_{sri}$ Refer to "(2)".

$$\gamma_{satellite} = \gamma_{sd} \left[1 + M \frac{\gamma_{rid}}{\gamma_{sd} + \cdot \gamma_{rid} + 1}\right] \quad (3)$$

$$\gamma_{satellite} = \frac{P_s |h_{sd}|^2}{N} \left[1 + M \frac{\beta_i^2 |h_{rid}|^2}{\beta_i^2 |h_{rid}|^2 + 1}\right] \quad (4)$$

Where β_i^2 ith relay amplifier gain $= \frac{P_{coop\,max}}{P_s |h_{sri}|^2 + N}$, the noise variance $N = KT_{sys} B_s$, P_s satellite or APs downlink power, $P_{coop\,max}$ = cooperative max power, M= number of cooperative terminal [23].

Applying the same principle we can calculate the overall SNR at the receiving end, Assuming APs used as a source and MRC at the destination terminal.

$$\gamma_{APs} = \gamma_{ad} \left[1 + M \frac{\gamma_{rd}}{\gamma_{ad} + \cdot \gamma_{rd} + 1}\right] \quad (5)$$

$$\gamma_{APs} = \frac{P_s |h_{ad}|^2}{N} \left[1 + M \frac{\beta_i^2 |h_{rd}|^2}{\beta_i^2 |h_{rd}|^2 + 1}\right] \quad (6)$$

Assuming all cooperative terminal have same characteristics (i.e $\gamma_{ad} = \gamma_{ar}$)

Where $\gamma_{ar} = \frac{|h_{ar}|^2 E_s}{N_{ar}}$,$\gamma_{rd} = \frac{|h_{rd}|^2 E_i}{N_{rd}}$ and $\gamma_{ad} = |h_{ad}|^2 \frac{E_s}{N_{ad}}$ are the instantaneous signal-to-noise ratio (SNR), between APs and cooperative terminal, cooperative terminal and destination terminal, and APs system and destination terminal respectively .

III. Coverage And Capacity For Wireless System

Coverage and capacity are important issues in the planning process for wireless network. Although there are three distinct standards in 3G networks (each used in different parts of the world), WCDMA, CDMA2000 and TD-SCDMA, the general planning process and overall objectives are the same. The Long Term Evolution (LTE) is the latest step in moving forward from the cellular 3rd Generation (3G) to 4th Generation (4G) services. LTE Advanced is a mobile communication standard, formally submitted as a candidate 4G system to ITU-T in late 2009, was approved into ITU, International Telecommunications Union, IMT-Advanced and was finalized by 3GPP in March 2011 [27].

For coverage and capacity analysis first, the coverage areas are designated. Next, through capacity and coverage calculations, the required number of access points per coverage area is determined. These access points are then physically placed, their power-levels set to fix the cell dimensions. Radio link coverage in the cell site can approximately be modeled by the empirical and deterministic radio propagation models.

A. Free Space Path Loss Model (FSPL)

FSPL is a decrease in signal strength (in watts) encountered by an electromagnetic wave, which results from a line-of-sight path through free space. In such case, the path loss experienced by the radio signal with the distance is given by [30].

$$PL_{dB} = 20\log(d_{Km}) + 20\log(f_{MHz}) + 32.46 \quad (7)$$

Where d_{Km} = distance between the transmitter and receiver in km f_{MHz} = frequency of operation in megahertz

B. Cost 231-Hata Model

This model has been developed based on experimental measurements conducted by Okumura in Tokyo (Japan) region [28, 31]

$$PL_{(dB)} = 46.3 + 33.9\log(f) - 13.02\log(h_b) - a(h_r) + [44.9 - 6.55\log(h_b)].\log(d) + c \quad (8)$$

Here f represents the frequency in MHz, d denotes the distance between the transmitter & receiver, h_b & $h_r$the effective transmitter (base station) antenna height (in meter) ranging from 30m to 200m and the effective receiver antenna height (in meter) ranging from 1m to respectively.

The parameter c is zero for suburban & rural environments while it has a value of 3 for urban area. The mobile correction factor $a(h_r)$ for urban area is defined as:

$$a(h_r) = 3.2(\log(11.75h_r))^2 - 4.97 \text{ for } f \geq 300\text{MHz} \quad (9)$$

and for rural & suburban areas its is as follows:

$$a(h_r) = (1.1\log(f) - 0.7)h_r - (1.56f - 0.8)\text{dB} \quad (10)$$

C. Standard Propagation Model (SPM)

Standard Propagation Model (SPM) is based on empirical formulas and a set of parameters are set to their default values. However, they can be adjusted to tune the propagation model according to actual propagation conditions. SPM is based on the following formula [29].

$$L_{model} = K_1 + K_2\log d + K_3\log H_{Txeff} + K_4 * \text{Diffraction loss} + K_5\log d * \log H_{Txeff} + K_6 HRxeff + Kclutter * fclutter \quad (11)$$

$L_{model} = K_1 + r^2$For hilly terrain, the correction path loss

When transmitter and receiver are in LOS is given by

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$$L_{LOS} = K_{1los} + K_{2los} \log d + K_3 \log H_{Txeff} + K_5 \log H_{Txeff} \log d + K_6 HRx + Kclutter * fclutter \quad (12)$$

When transmitter and receiver are not in line of sight NLOS, the path loss formula is

$$L_{NLOS} = K_{1NLOS} + K_{2NLOS} \log d + K_3 \log H_{Txeff} + K_4 * Diffraction + K_5 \log d * \log H_{Txeff} + K_6 HRx + Kclutter * fclutter \quad (13)$$

Where, $K_1$is frequency constant, K_2 is Distance attenuation constant d is distance between the receiver and transmitter (m), $K_{3,4}$ is correction coefficient of height of mobile station antenna Diffraction loss: loss due to diffraction over an obstructed path (dB), $K_{5,6}$is correction coefficient of height of base station antenna**,** K Clutter Multiplying factor for f (clutter)
F (clutter) Average of weighted losses due to clutter

$HRxeff$ = effective mobile antenna height (m)

Assume the cooperative terminal.is at a distance d km from the destination system Let P_{Coop}denote the average power transmitted by the cooperative terminal and $P_{distination}$ denote the average power received at the destination system (in decibels) then [35].

$$P_{destination} = P_{COOP} - P_L(d) \quad (14)$$

Where $P_L(d)$ is the mean path loss at distance d Km

After calculating the path loss and cell range d, the coverage area can be calculated. The coverage area for one cell in hexagonal configuration can be estimated with [34]

$$\text{Coverage area, } Sa = N.d^2 \quad (15)$$

The value of N for this paper is 1.95 (i.e. by considering three sectors).

D. Capacity and Cell edge SINR calculations

An equally important goal of cell dimensioning is to optimize the network's traffic capacity. The capacity and SINR are inter-related by the Shannon's formula [36].

$$C = Bx\log_2(1 + SINR) \text{in bps} \quad (16)$$

Where C is Capacity of the channel or throughput (bps). B is Bandwidth of the channel (Hz) and SINR = Signal to Interference- Noise Ratio (in linear scale).

The capacity of UMTS system is thus typically interference-limited rather than blocking-limited, since all mobiles and base stations interfere each other in uplink and downlink directions. Furthermore, the network (or cell) capacity is defined by the load equations that, on the other hand, set limits for the maximum number of users in a cell or for the maximum cell throughput [8].

As the downlink capacity of UMTS is related to transmit power of Node B and uplink capacity is related to numbers of users, uplink capacity is considered in this paper. If the number of users is Ns then for a single CDMA cell, the number of users will be [32, 33].

$$N_s = 1 + \left(\frac{W/R}{E_b/N_o} - \frac{\eta}{S}\right)\frac{1}{\alpha} \quad (17)$$

Where, *Ns* is total number of users, *W* is chip rate, *R* is base band information bit rate, *Eb/No* is Energy per bit to noise power spectral density ratio, η is background thermal noise, S is signal power, S-P (d) is shadow fading, S is UE power and P (d) is Propagation loss.

For WCDMA, the chip rate is 3.84 Mcps, and the channel bandwidth is 5 MHz. It is also necessary to consider the affects of multiple cells or intra-cell interference (β), cell sectoring (D), soft handover factor (H), Array antenna gain (A_g). Thus the capacity for WCDMA in UMTS yields:

$$N_s = 1 + \left(\frac{W/R}{E_b/N_o} - \frac{\eta}{S}\right)\frac{1}{(1+\beta)\alpha} \times D \times H \times A_g \quad (18)$$

IV. SIMULATION ASSUMPTION

TABLE I
SIMULATION PARAMETER

Parameter	**Value**
Number of Sectors	3
Max Power of TCH	12.21 dBm
Antenna Gain	18 dBi
Noise Figure	7 dB
Interference Margin	0.52 dB
Modulation	QPSK
Slow fading margin(Dense Urban)	2 dB
APs Platform Height	22 Km
Slow fading margin(Dense Urban)	9.71 dB
Slow fading margin(Sub Urban)	4.79 dB
Area coverage probability	95 %
Propagation model(Dense Urban)	SPM
Propagation model(Sub Urban	Cost231-Hata
Bandwidth	20 MHz
Duplex Mode	FDD
Satellite Max. EIRP	100 dB
Cooperative terminal frequency	2600 & 2100 MHz
Earth station to satellite distance	39000 Km

TABLE II
SIMULATION PARAMETER FOR UMTS

Parameter	Value
Chip rate	3840 Kbps
Antenna Gain	18 dBi
Body Loss	3 dB
Max Power of TCH	43 dB
Cooperative terminal Max. power	250mw
Voice Activity	0.5
Slow Fading Standard Deviation	11.7 dB
Slow fading margin	12.6 dB
Interference Margin	6 dB
Cooperative terminal frequency	2100 MHz
User data rate	12.2 Kbps
BTS height	30 m
MS height	1.5 m

TABLE III
K-PARAMETER FOR SPM

SPM -Parameter		**Value**
K Values	Dense Urban	Sub- urban
$k1$	27.45	16.45
$k2$	44.9	44.9
$k3$	5.83	5.83
$k4$	0	0
$k5$	-6.55	-6.55
$k6$	0	0
Clutter loss	0	0

V. SIMULATION RESULTS ANALYSIS

In order to illustrate the above theoretical analysis, the paper performed some computer simulations using Matlab software in this section. The system coverage and capacity evaluated in two different cellular networks (UMTS and LTE) for different BER in dense urban and suburban environment have been carried using MATLAB based simulations for common prediction techniques such as COST-231 Hata model and SPM. The paper studies wideband channels at 2.1GHz and 2.6GHz in advanced Network. The methodology consists of a single Satellite, APs and a multiple cooperative terminal (terrestrial). Each platform is equipped with a multi-spot beam phased array antenna to create the spot beams or cells on the ground. APs can be used as independent source and as relay (amplify and forward to the destination) when it receive a signal from Satellite.

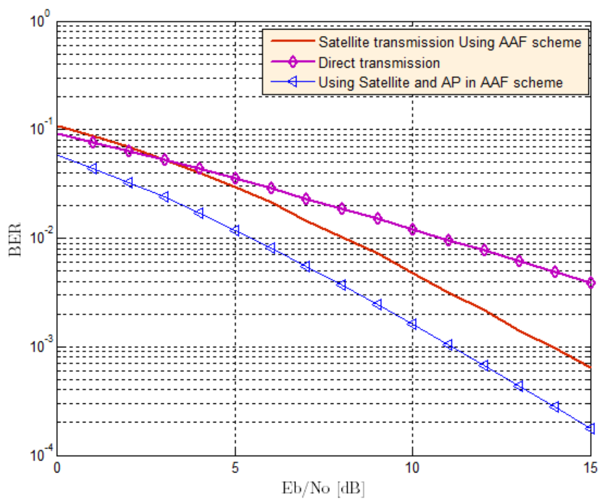

Fig. 2 BER performance of amplify-and-forward (AAF) for Satellite, APs and Terrestrial network.

Fig. 2 shows that destination terminal received better Eb/No in proposed model (i.e. integrated network improves markedly over a comparable non cooperative and non-integrated system), for example at BER 10^{-2} the Eb/No improve 3 dB and 6 dB in satellite transmission using cooperative protocol and integrated (Satellite, APs and terrestrial network) system respectively. In other word two significant results can be noted. First, destination nodes received better signal by cooperating Satellite system. Second, more interestingly, integrated system also improves there performance (both coverage and capacity) significantly.

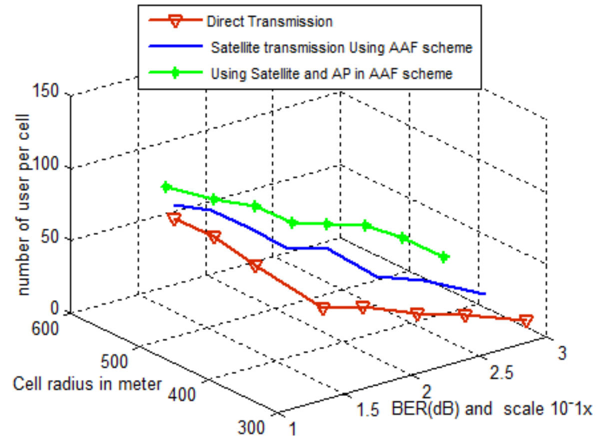

Fig. 3 Number of 12.4 Kbps User per cell Versus Cell radius with different BER for UMTS network

In Fig. 3, Number of user per cell vs. cell radius is shown for varying bit error rate with the information bit rate of 12.2 kbps (speech user). Fig. 3 shows that when the BER 10^{-2} , the number of users per cell reach 16, while with cooperative satellite and integrated signal from APs, the number of users per cell increase, i.e. 46 and 65 respectively. In addition to this when BER 10^{-3} the cell radius also increased , i.e. 0.33 Km, 0.37 Km and 0.45 Km 65 in direct transmission, satellite transmission using cooperative protocol and Satellite & Aps (using AAF cooperative scheme) respectively. That is to say, the performances of the system increase both capacity and coverage.

The result of this study important for capacity and coverage balance and suitable in emergency situations or for supplemental capacity and coverage in hot-spot, Since real markets are characterized by irregular network layout, complex propagation patterns, and inhomogeneous traffic distributions that give each cell its own shape. The coverage measure should be weighted by the local traffic density to capture the network-wide fraction of users who receive adequate service. However from this model (see Fig. 3) the capacity and coverage can be improve at the same time. In addition to this APs system can be repositioned if necessary and repaired on the ground in case of failure, their payloads can be reconfigured according to current needs and integrated the terrestrial system.

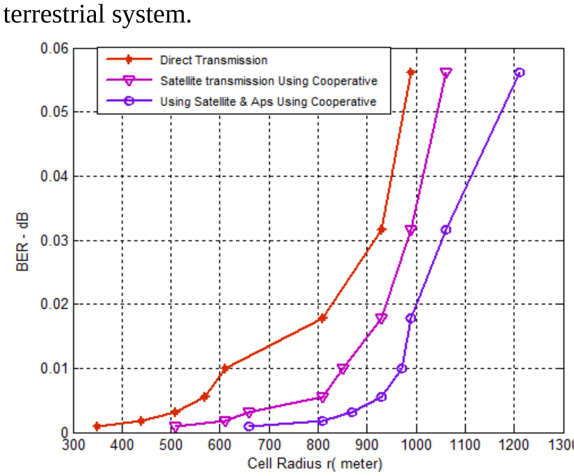

Fig. 4 Bit Error Rate (BER) versus the cell radius for LTE Dense Urban area (2600 MHz)

Fig. 4 shows the cell radii for LTE 2600 MHz under the assumption of dense are environment for different bit error rate. Cell edge SINR for different bandwidths can be calculated Refer to "(16)". It has been shown that at BER 10^{-2} the cell radius increase 7% - 38 % and 22%- 59% in satellite cooperative system and integrated system respectively .

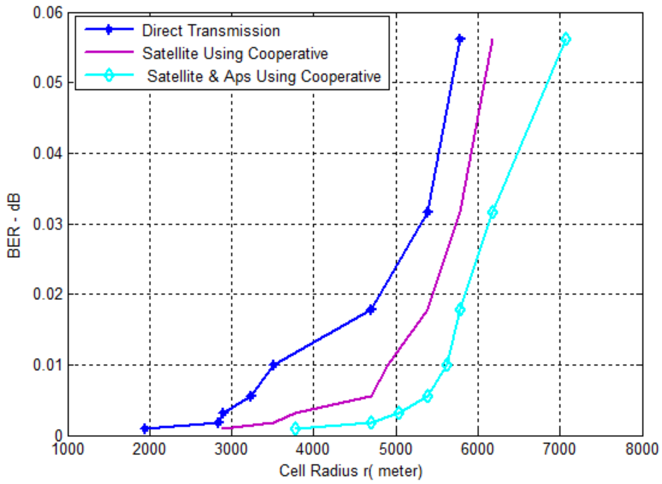

Fig. 5 Bit Error Rate (BER) versus the cell radius for LTE Sub-Urban area (2100 MHz)

Fig. 5 shows the comparison of cell radius of LTE 2100 against BER. Refer to "(15)". The coverage area (for direct transmission) in the measurement route is 0.726 km^2 for LTE 2600MHz and 6.8 km^2 for LTE 2100 MHz when BER10^{-2}. However, in the integrated system the coverage area 1.9 km^2 and 10.9 km^2 in LTE 2600 MHz and LTE 2100 MHz respectively. It can be observed that the cell radius (coverage area) increased BER decreased and coverage increased when we use the integrated system. Link modulation of QPSK with coding rate of 0.19 has been taken into account in the link budget.

VI. CONCLUSIONS

This paper considered the analysis by simulation of an integrated communication system for a scenario which consists of a Satellite, Aerial Platform (AP) and mobile terrestrial transceivers (such as UMTS and LTE). The performance of LTE and UMTS system over the Satellite, APs and terrestrial integrated model is investigated. The performance is measured in terms of the bit error rate versus capacity (number of user per cell) and coverage (cell radius). It is observed from the study that the numbers of user per cell are less for direct transmission as compared with cooperative satellite and integrated system. The results indicate a good feasibility (low-cost, flexible, interoperability, better performance, etc) for the wireless communication system proposed and analyzed.

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