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System Selection Algorithm for Heterogenous Radio Access Networks

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ABSTRACT
Deployment of new radio technologies in the mobile world has been steadily gaining momentum as an alternative to meet the ever increasing demands of customers. This has especially been motivated by the existence of applications that make available to ordinary users a host of services that require higher spectral efficiency and data rates. LTE (Long Term Evolution) and LTE Advanced (LTE-A) with an enhanced air interface and optimized packet data architecture, an all IP network, is envisioned to provide enhanced data rates, reduced latency and cost efficient operations. The deployment of LTE concurrently with the existing legacy cellular systems, such as UMTS in the same cell sites, has proven to enhance the network resources available to the operators. Such deployment, however, is accompanied with many challenges such as mobility and load balancing. The diversity and availability of services which can be supported by several radio access networks, such as legacy 3G and LTE, make the management of radio access selection rather complex. In this paper, we propose a multi-criterion cell selection algorithm for multi radio environment (3G and LTE) based on service request, user profile and user equipment capabilities.

General Terms
Algorithms, Cell Selection, Deployment, and Interworking

Keywords
Algorithms, LTE, UMTS, and Cell selection

1. INTRODUCTION
Mobile operators' deployment of LTE in the same cell site as UMTS has started the research on several technical issues including cell selection. Multi-access network planning and radio resource management, which are essential aspects in the multi-radio/multi-access technology deployment, are further complicated by the requirements to support diverse traffic classes and services that are standardized by 3GPP community [1].

One of the main objectives of evolved packet system (EPS) among others are (1) to provide a support of a variety of different access systems, and (2) to ensure service continuity and seamless mobility between these access systems.

3GPP standard community has been looking for ways to enhance UMTS/HSPA and LTE internetworking. Several proposals are under discussion. Such proposals have been mainly focused on two scenarios: small cell scenarios and macro cell scenarios. Small cell scenarios are of two deployment types, first, UMTS cells are used to provide full macro coverage while the E-UTRAN are deployed for capacity improvement in small cells for traffic offloading in hot spot areas. Second, in indoor deployment areas where the coverage is through E-UTRAN while for coverage extension, UMTS cells are used. However, in macro cell deployments, two scenarios are envisioned as well, first, the UMTS cells provide full coverage while E-UTRAN provides some area coverage. Second, both systems UMTS and E-UTRAN are deployed to cover the same coverage area.

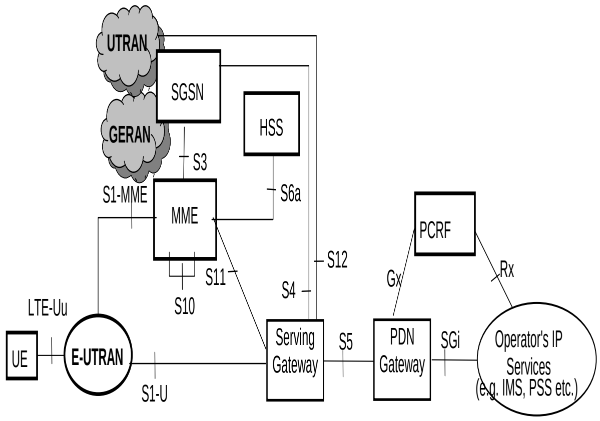

Fig 1: Non-roaming Architecture [2]

Ensuring service continuity is vital for mobile network operators. Call drop and service interruption have severe impacts on customer perception of the service and operator. The EPS shall support a variety of traffic services such as but not limited to voice, video, messaging and file exchange. Such services are delivered to users based on certain agreed up on QoS of legacy systems (GSM/UMTS) or better. The QoS measures from the user perspective can be divided into four categories including network access at all times, service access, service retain-ability and service integrity throughout the use of the service.

In the following section, Section II, we present a literature review, in Section III a description of the proposed selection algorithm is presented, in section IV, Radio Access Technologies and traffic classes is presented, in section V we describe the simulation environment and in Section VI we present the simulation results and discussion, and in Section VII we conclude the paper and provide hints for future work.

2. LITERATURE REVIEW
The LTE architecture is simplified to become a more efficient all-IP system that is optimized for packet traffic. For example Radio Network Controller (RNC) used in early 3G releases for Radio Resource Management (RRM) functions is removed and its intelligence is moved to the Evolved Node B (eNodeB). Another considerable difference to legacy cellular

systems is that there is no circuit switched domain in LTE architecture. The core network is solely all-IP, and therefore control data and user data as well as voice are all transferred on top of packet switched IP-protocol. Therefore, a fundamental change to the mobility architecture and services has been introduced when compared to the legacy 3GPP technologies. UMTS has a radio network controlling element (Radio Network Controller) which possesses the necessary intelligence and signaling capabilities.

Coexistence of LTE and UMTS/HSPA radio technologies is the most likely scenario in the near future when the same operator is deploying the new LTE RAT in the same cell site of UMTS/HSPA. One of the envisioned scenarios is illustrated in figure 2.

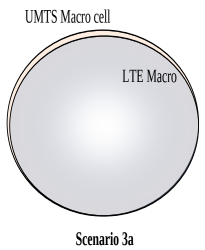

Fig 2: Deployment Scenario [3]

Devising a mechanism for seamless internetworking between LTE and UMTS/HSPA is an essential step to facilitate multi RAT deployment. Inter operation between LTE and UMTS can enhance the radio resources of the operator as each of the internetworking technologies, LTE and UMTS/HSPA RATs, has its own radio resources. The collection of these radio resources is forming one big radio resource pool under the administration of one multi-standard radio (MSR) base station. Such MSR base station is characterized by the ability of its receiver and transmitter to process two or more carriers in common active RF components simultaneously in a declared RF bandwidth, where at least one carrier is of a different RAT than the other carrier(s).

For efficient utilization of the radio resource pool, the operator needs to devise advanced management algorithm for call redirection and user relocation. Such approach can have a positive impact on the network resource utilization and reduce the resource burden on the core network and at the same time enhance mobility and load balancing. Internetworking between LTE and UMTS/HSPA can improve load balancing among RATs depending on the deployment scenarios as envisioned in the standard [3]. Currently the load balancing handover is based on the resource usage in each cell. However, resource usage does not indicate the level of user satisfaction by the service or what is called “better user experience”. At the same time, such problem is complicated by other issues, such as; the diversity of the services, the load information exchanging between UMTS and LTE via Radio Access Network Information Management (RIM-PDU). In this paper, we are presenting an algorithm for load balancing based on service request by the user and UE capabilities. The signaling problem due to inter RAT communication is not considered. The scenario we are basing this algorithm on is full coverage scenario as depicted in figure 2.

With the deployment of many radio technologies and the planned wide installation of such radio technologies in the same cell site and by the same operator; the need for load self-balancing networks has been on the rise for the last few years. The starting point was the introduction of Self Organizing Network (SON) by the 3GPP community [4, 5].

One of our aims in this research is to develop an algorithm based on several criteria to enhance the decision making process of the operators network and to minimize sudden changes in heterogeneous cell loads in order to optimize the overall system capacity and efficiency. In [6], the authors proposed two fuzzy models for load balancing. Besides the key performance indicators, the two models use load indicators as well for a more accurate load balancing. The virtual cell load was computed based on the number of users in the cell compare to the number of resources used. The same approach has been proposed in [15]. The number of unsatisfied customers was measured based on the cell virtual load and the number of customers in the cell. The authors developed two models, the Load distribution index and the unsatisfied user model. For load distribution index, the virtual cell load and the overall system load are used as input parameters. The number of unsatisfied users is also used as an input parameter along with the virtual load and overall system load as input parameters. The authors are emphasizing the need for human intuition to solve such nonlinear problem. In [7], the authors proposed to use fuzzy logic controller (FCL) for handover parameters optimization. The controller makes use of the reference symbol received power of the serving cell and the adjacent cell. The second parameter used is the load of the cells based on the mean number of time slots occupied, while the third parameter is the current value of handover margin. The authors claim that the call blocking ratio has been improved by using FCL for self-optimizing handover margins in LTE networks. In [heterogeneous service], the authors formulated the load balancing problem as multi objective optimization problem based on heterogeneous services in LTE. Two classes of service have been considered, constant bit rate and best effort services. The constant bit rate users are assigned the required resources first and then the residual resources are assigned to the best effort users. During admission control, the user with constant bit rate takes priority if resources are available. This is an indication that the constant bit rate users are taking priority over the best effort users and subject to the total resources available in the system. The authors claim that the proposed load balancing algorithm can enhance the blocking probability of the constant bit rate services and enhance the best effort services throughput.

The models and algorithms presented in the above research and within references, to provide a solution for self-organizing networks are limited to a single deployment of one technology; LTE technology. However, the future of cellular systems deployment is to deploy multiple radio technologies (RATs) in the same cell site. Moreover, an efficient algorithm for an efficient cell reselection can enhance greatly the load balancing of the overall system and reduce the penalty of signaling due to cell reselection and handover.

3. THE PROPOSED SELECTION ALGORITHM

The selection algorithm proposed in our implemented scenario is based on the deployment of LTE cells with full overlap coverage as of the specified in 3GPP standards [3] and illustrated in figure 3 below,

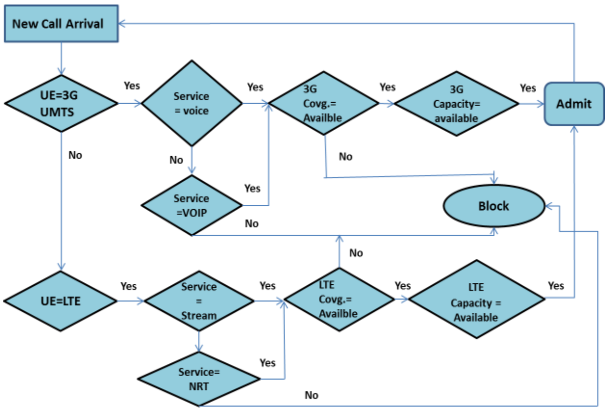

Fig 3: The proposed Algorithm

The call arrival follows the Poison distribution; the system needs to verify what the user equipment (UE) type is and its capabilities. We have realized two types of UE, 3GUMTS type for accessing 3G system and LTE UE for accessing LTE system. After that the system needs to identify the requested services by the UE. If the UE is of type 3GUMTS then the services that are available either voice or VOIP. If 3G system coverage is available then the system is checked for capacity; otherwise the system blocks the user and move to new call arrival. Voice and VOIP services are modelled as a poison distribution with µ mean service time of 120 units of time. However, if the UE is LTE then the services available are streaming or non-real time services. The streaming services can be either VOIP, video streaming or mobile TV. The non-real time (NRT) services are divided into NRT1 and NRT2 as illustrated in table 1. Following the same algorithm all such services are directed to LTE. The reasoning behind the selection is that any one of these services will at least consume more than 50% of the resources available in 3G cell. By directing the selection process to LTE we will be able to service more customers with legacy services such as voice. It is our belief that the above algorithm will distribute the resources in the system efficiently and will enhance the selection/reselection process of the total network and improve the blocking probability of the total system.

4. TECHNOLOGIES AND TRAFFIC CLASSES

4.1 UMTS

UMTS networks or legacy UMTS NodeBs are connected to the core network through the Radio Network Controller through circuit switched side to the Mobile and Switching center (MSC) and the other to the packet switched side through serving GPRS Service Node (SGSN). Radio resources of UMTS are split between the two technologies. Legacy voice call is the main service that is provided by UMTS. The target signal-to-noise ratio (Eb/Nt) determines the quality of service and offered through virtual circuits. Services and required signal to noise ratio are described in 3GPP standards [1 and 12]. UMTS cell capacity can be described as:

$$\eta DL = \sum_{n=1}^{N} v \frac{\left(\frac{Eb}{N0}\right)}{W/R} \left[(1-\alpha)+i\right] \qquad (1)$$

Where W is the spreading bandwidth of 3.84 Mega chip, R is the service bit rate, Eb/N0 is the energy per bit to the total noise spectrum density, ν is the activity factor and i is the interference, ηDL is the downlink capacity and α is the orthogonality factor. 3G uses codes to separate and identify traffic for each user. These codes are unique, but due to multi path propagation the code orthogonality is lost resulting in interference between users signal. Perfect orthogonal codes represent 1 in the above equation while in practice for multi path channel the value between 0.4 and 0.9 is used.

4.2 LTE

Long Term Evolution (LTE) networks are based on Orthogonal Frequency Division Multiple Access (OFDMA) technology. The LTE system that is realized in this paper comprises 50 physical resources blocks (PRB) each has 12 subcarriers in accordance with LTE standards. Base station power is divided equally among the total PRBs. However the resources are distributed based on the service required and following Shannon formulas as

$$R = \log_2(1 + SINR) \qquad (2)$$

Where SINR is the signal to interference plus noise ratio that is reported by the user equipment and R is instantaneous data rate that the user can achieve per Hz. For a specific modulation and coding scheme a certain SINR is required to be achieved [8, 9].

4.3 Traffic Classes

In Table 1, a list of the traffic classes and services that we are considering in this performance study as per the 3GPP standard [1]. We have also shown a file size of 5GBytes for NRT and for video streaming as well.

Table 1. Traffic classes

Traffic Class	Sub Class	File Size	Data Rate
Voice	Voice call		16Kbps
Streaming real-time	VoIP	5GByte	16Kbps
	Video Str.		144Kbps
Streaming Non real-time	MTV		384kbps
	NRT1		512kbps
	NRT2		1024Kbps

In this scenario elastic services are not considered, as well as all services are considered to be of constant bit rate. In other words the service once admitted and started are there to finish the download. The customer services are of different data rates as illustrated in table 1. The quality of services provided to all users is the same, constant bit rate (CBR). It is up to the scheduler to enforce this policy. In reality this is not the case, but for the sake of establishing a base line we have elected to do so. In the future we will consider the use Non-Real time services to be elastic services.

5. SIMULATION ENVIRONMENT

The simulation was carried out using a customized version of the Discrete Event simulator described in [11] and depicted in figure 4. The simulator can accommodate 5 different deployment environments, namely, free space, rural, suburban, urban and dense urban. The deployment of the cells in our evaluation was realized for dense urban environment. The path loss model used is as described in [12].

The simulation scenario as illustrated in figure 5, assumes dense urban environment with LTE cell deployment in the same cell site of legacy WCDMA cells and coverage area of 500 m. The deployment scenario is realized for 18 cells, 9 LTE and 9 UMTS in the same location. The UMTS capacity follows equation 1 in the downlink while the data rate for

LTE cell is 30Mbps assuming single input single output antenna deployment [13].

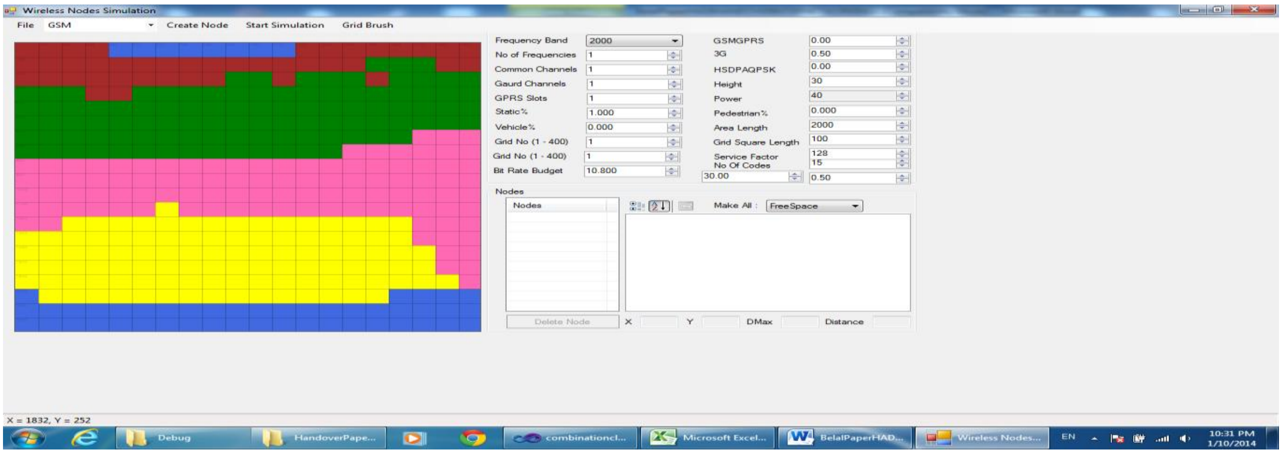

Fig 4: The Simulator

The capacity for the UMTS cells is capped at 80%, while the LTE cells are maximized by individual cell capacity. The customer locations follow a uniform distribution, customers arrival to the system following Poison process with inter arrival rate of 1/λ, where λ is ranging from 1 to 13. However, the service of the customer also follows a Poison distribution with µ as 1/120 of unit time for voice and voice over IP (VOIP) services. The other streaming services and non-real time services are as depicted in table 1. The requested service for all streaming and non-real time services is to download a file of size 5Gbyte as mentioned above.

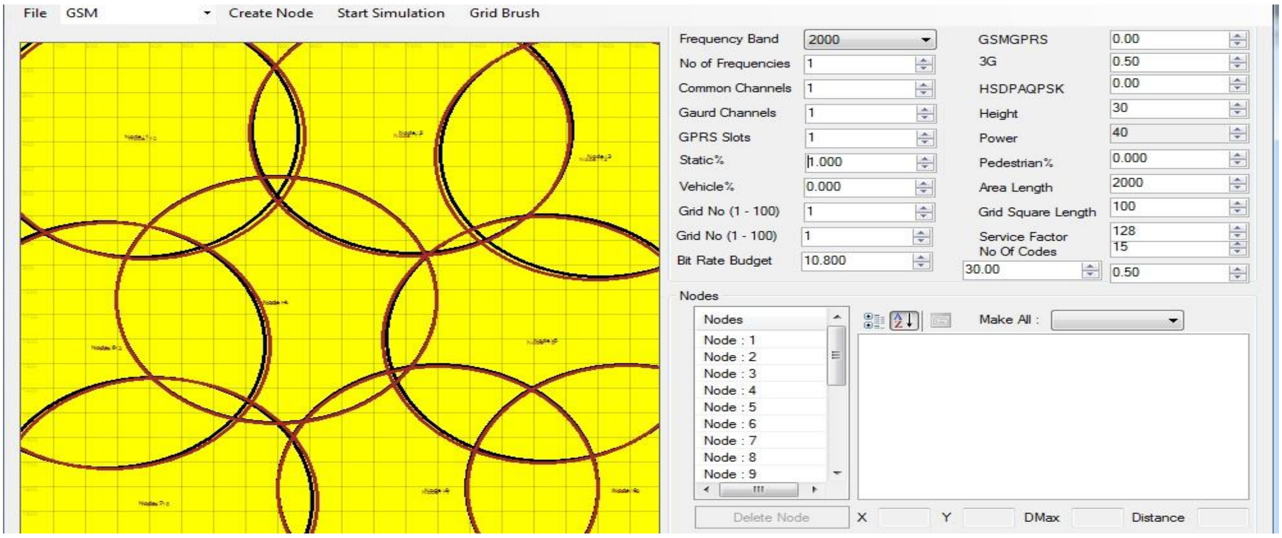

Fig 5: The Deployment Scenario

The investigated scenario is depicted in Table 2 below:

Table 2. Simulation Scenarios

Scenario 1	**Percentage**	**Service**	**Percentage**	**Service Type**	**UE Category**
Traffic Distribution	50% 3GUMTS	Voice	50%	voice	3GUMTS
		Streaming	50%	VOIP	
	50% LTE	Streaming	50%	VOIP, video, MTV	LTE
		NRT	50%	NRT1 and NRT2	
Scenario 2		Voice	50%	voice	3GUMTS
Traffic Distribution	25% 3GUMTS	Streaming	50%	VOIP	
	75% LTE	Streaming	50%	VOIP Video MTV	LTE
		NRT	50%	NRT1 and NRT2	

6. SIMULATION RESULTS

The first scenario was carried out to illustrate the performance of the total system when RAT deployment as illustrated in figure 2 where total overlap is realized between the UMTS system and LTE system. The proposed Algorithm is realized and the simulation study has been setup as in table 2. The first scenario was done for 50% 3GUMTS UEs and 50% LTEs.

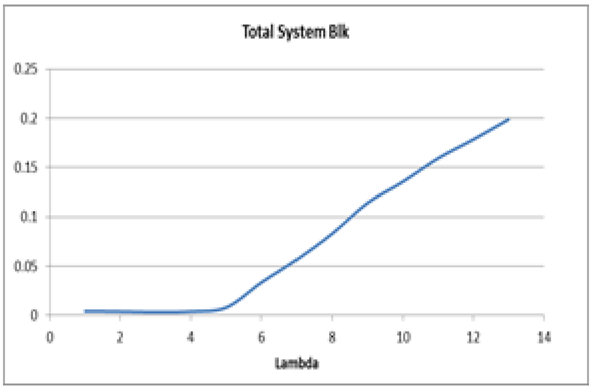

Fig 6: System Block.

The simulation results show that for the total system and as illustrated in figure 6, the blocking probability reaches 2% when Lambda is approximately 6. Keep in mind that this is a great improvement when considering the 3G system only. Furthermore this blocking probability is for the actual service denial as well as for coverage denial. In other words, this might be very well lowered when we have full coverage of both systems when considering the same scenario.

For conversational services, voice and VOIP, the blocking probability is illustrated in figure 7. The results indicate that the blocking probability is when lambda around 5.5, we need to keep in mind that in our simulation, none of the circuit switched (CS) fall back scenarios had been realized. This study is conducted on the resources allocation for each system. The composite of the results may change when such scenarios are incorporated in the system.

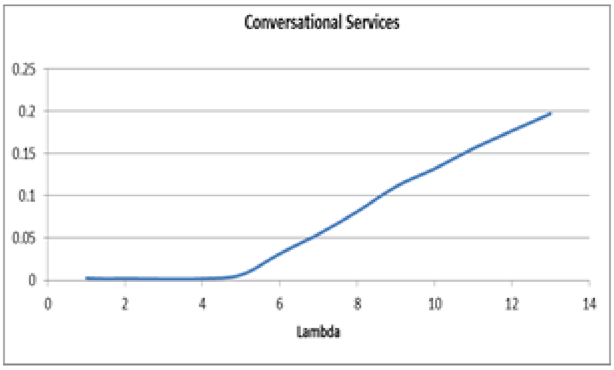

Fig 7: Conversational Services Blocking

For streaming and no real time services, the results indicate that the blocking probability is not noticeable around .002; the reason behind such results is that 50% of the traffic was for conversational services which is the dominant service provided by the cellular systems. It is also interesting to find that the load of LTE cells is moderate in such scenario as presented in figure 8.

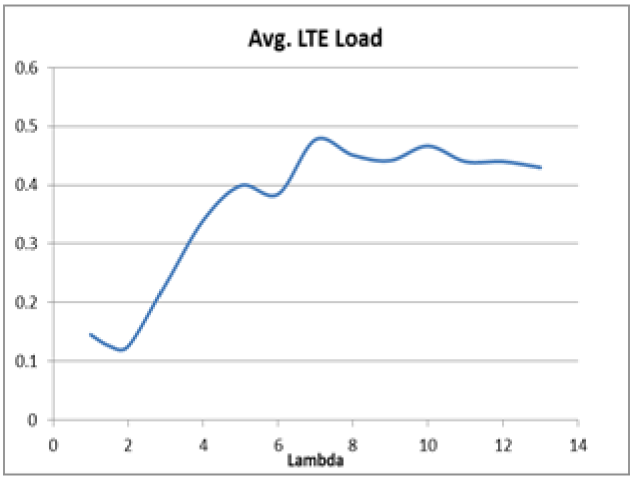

Fig 8: LTE Load

As shown in figure 8, the resources consumed by the LTE cells are around 50% of the total resources realized for the cell. This is a motivation for us to consider a new study based on the CS fall back scenario.

For the realized second scenario as depicted in table 2, where 25% of the Lambda was for conversational services and 75% is considered for streaming and none real time services, the blocking probability for the total system is depicted in figure 9 below.

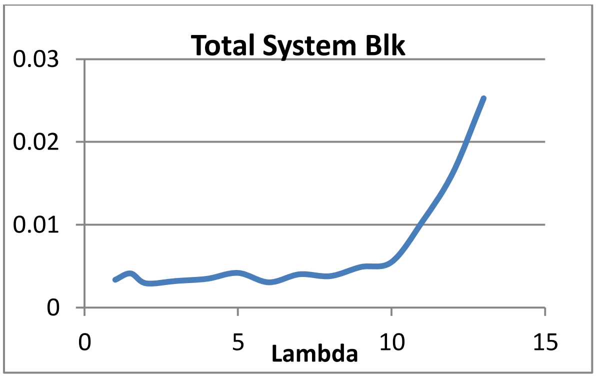

Fig 9: Total System Blocking Scenario 2

We notice from figure 9, that the system blocking probability has improved to Lambda around 13. This is due to the capacity of LTE system as well as that the selection procedure has directed 75% of the traffic to that system. For conversational services and as depicted in figure 10 below, the blocking probability reaches 2% when Lambda is around 13.

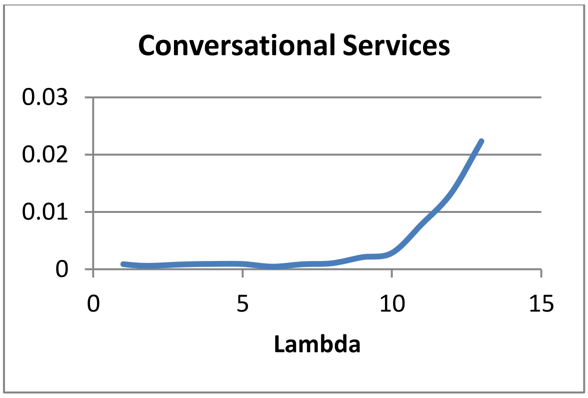

Fig 10: Conversational Services Scenario 2

The average LTE system Load for the scenario is illustrated in figure 11 below.

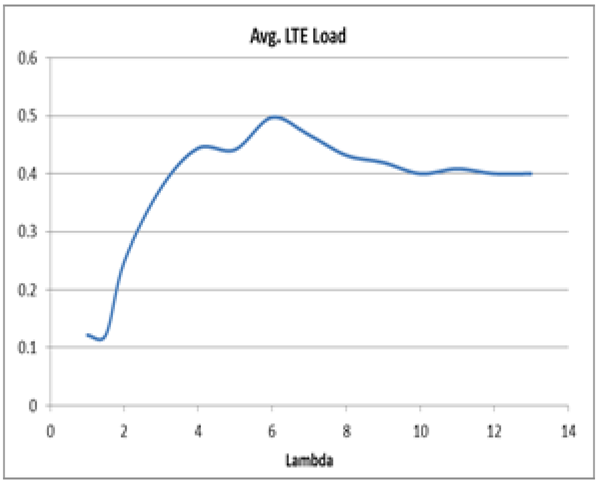

Fig 11: LTE Load Scenario 2

The LTE system resources consumed by the users is around 50% of the total resources realized by the system. A comparason with with the system in scenario 1 in table 2 reveils that the system is not fully loaded in both cases and that the load was kept at the same level.

A comparison of the the results from figure 6, figure 7, figure 9 and figure 10 show that the total blocking probability is strongly influenced by the blocking probability of the conversational services.

7. CONCLUSION

The proposed multi-criterion cell selection algorithm is essential to provide system stability and leads to enhanced blocking probability of the total system. Initial results show that the blocking probability can be enhanced when the traffic is directed by the proposed algorithm. The results also indicate that the operators will be better informed on the utilization of their existing as well as deployment of new equipment and technologies such as advanced UEs. It has also been shown that the traffic distribution can impact the system blocking probability. However, it is following the conversational services as it has been pointed out when comparing figures 6 through figure 10. For the LTE system, it was not evident that the system has been influenced by increasing the traffic distribution by 25% as the LTE system Load has been constant at 50%. This is an interesting finding for the design of a load balancing algorithm for such deployment as the customer experience and satisfaction influence the selection criteria. Future research will consider mobility in the system as it affects cell selection and reselection algorithms.

8. ACKNOWLEDGMENTS

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