Comparison of Policy Realization Strategies for LTE Networks

Usama Mir and Loutfi Nuaymi
Institut Mines TELECOM;
TELECOM Bretagne, Universite europeenne de Bretagne
Rennes, France
{usama.mir, loutfi.nuaymi}@telecom-bretagne.eu

Abstract—**Efficient radio resource usage and quality of service (QoS) provision are important criterions in order to choose the right QoS policy for the LTE operators. In our previous work, we have proposed to add a new database named as BSLRC (Base Station Load and Radio Conditions) to optimize the operator policy with regard to the radio efficiency [1]. Some concrete voice capacity estimations were also proposed. In this paper, we extend our earlier work by addressing some novel concerns. As a first step, we start by calculating the signaling load due to the use of BSLRC. Then, for voice services the BSLRC method is compared with the explicit congestion notification (already proposed for LTE systems). Both BSLRC and ECN (Explicit Congestion Notification) share the same objective of optimizing the choice of codec rate with regard to radio use efficiency. We also propose some capacity estimates for video services as an extension to our previously proposed voice capacity estimations over LTE systems.**

Keywords-radio resources; QoS; voice and video services; PCRF; LTE; signaling load

I. INTRODUCTION

Recently the telecommunications industry has shown a huge amount of advances and improvements offering subscribers and operators with increased spectrum efficiency, peak level data rates, higher portability, low latency, and optimized QoS (quality of service). Due to this high proliferation of telecom industry, LTE (long term evolution) system also known as E-UTRAN (Evolved UMTS Terrestrial Radio Access Network) was emerged as a part of 3GPP (3rd Generation Partnership Project) release 8. Along with rendering access to high quality internet services (such as voice over IP, multimedia streaming, internet TV, etc.), LTE will also provide connectivity to mobile devices for these applications [2]. As a result, the QoS and signaling control must be optimized in order to configure radio access network to meet the requirements of these high quality services [3].

To efficiently adjust the above mentioned requirements, LTE includes several new technical features. For example, it uses OFDM (Orthogonal Frequency Division Multiple Access) on DL (Downlink) and SC-FDMA (Single Carrier Frequency Division Multiple Access) on UL (Uplink) providing both the flexibility and higher radio spectrum usage [4]. In OFDMA, the frequency spectrum is divided into blocks called the PRBs (Physical Resource Blocks). A PRB is a set of OFDMA sub-channels used during a fixed time interval. The allocation of a PRB for a transmission is associated to the choice of modulation and coding schemes, i.e., the MCSs. Further, bandwidth ranges of 5-20 MHz are supported as well as smaller than 5 MHz (1.4-3 MHz) to add more flexibility. End-to-end QoS management and control shall also be provided to support voice and video based applications. The interested readers can refer to [4] for further details on LTE.

Another important element in LTE systems is the PCC, (Policy and Charging Control) providing among other, end-to-end QoS Control [5]. [6][7] describe PCC in detail where the PRBs and associated MCS are allocated in a centralized open service access architecture and the PCRF (Policy Control and Charging Rules Function) is considered to be the central element [8] of PCC as reminded below. This architecture allows the combination of new third part service providers and the personalization of subscriber services over wireless all-IP networks in order to provide optimal operator policy, higher user-service quality, efficient use of the spectrum, cost reduction and flexibility.

In relation to above, some research efforts have been done in the recent past to investigate several research issues related to PCC (especially PCRF) and its decision policy. In [9][10], the important concern of optimized session and bearer control signaling for PCC is addressed. Several types of signaling such as service activation, network initiation, bearer and session establishment are defined and some analytical expressions based on Laplace and Poisson processes are proposed to measure the signaling overhead. Slightly different, the works in [11][1] suggest some evolutions to LTE architecture. The NPF (Network Policy Function) is presented in [11] as a novel element for LTE systems acting as an intermediary node between the access network and the PCRF architecture, respectively. The NPF applies operator policies based on network load situation (such as normal, overload, emergency) or time of the day (e.g., day, afternoon, night) in order to facilitate flexible core network sharing. While in [1], a new database named as BSLRC (Base Station Load and Radio Conditions) is proposed for LTE architecture in order to optimize the operator policy with regard to the radio efficiency. The BSLRC contains the IDs of eNodeBs, the percentage of PRBs used and the observed MCS that can be consulted by the PCRF to efficiently perform its QoS decisions. Another core mechanism to adapt the QoS policies to the radio network load is known as ECN (Explicit Congestion Notification) [12]. ECN was included in Rel. 9 of 3GPP to

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support speech services in LTE systems [13][14]. Basically, ECN is an AQM (Active Queue Management) scheme [15] by which the network can notify about the congestion to its senders and receivers, so that the senders can reduce their transmission rates, before the packets are forced to drop or the end-to-end delay occurs. By interacting (for example) with the ECN-policer [16][17], the PCRF can acquire the network congestion information and based on this information a few necessary measures (such as rate reduction, packet dropping) can be taken to provide operators with better QoS decision policy.

In this paper, we extend our previous work [1] as well as address some important concerns which remained unanswered in above literature. At first, we calculate the signaling load for the BSLRC which help us visualize the impact of adjusting it within the LTE framework. Then, we provide a brief comparison between the BSLRC and ECN. Both of them share the same objective of optimizing PCRF's radio resource assignment policy, thus our comparison focuses on the pros and cons of BSLRC and ECN. We further propose some simple capacity estimations for video services in order to illustrate the interest of proper radio resource usage and QoS by choosing right policy for a service. An adjustment of these video estimations with our previously proposed voice capacity estimations [1] is also shown with the help of a graphical example.

The rest if the paper is organized as follows. In the next section, a general overview of an LTE system and its main elements is given. In Section III, we measure the signaling load between the eNodeBs and the BSLRC. Pros and cons of the BSLRC and ECN are provided in Section IV. The video capacity estimations and their adjustment with voice services are described in Section V. Finally, conclusion and future perspectives are provided in Section VI.

II. OVERVIEW OF LTE ARCHITECTURE

The main elements of an evolved LTE architecture along with the possible inclusion of our proposed BSLRC database are shown in Figure 1, where BSLRC is detailed in the next section. In the corresponding figure, the core network, the EPC (Evolved Packet Core) is made of the following main functional entities, some of them eventually combined in a same hardware element in different vendor configurations.

The MME (Mobility Management Entity) performs mobility and session management functions. It also manages resource allocation and bearer control [18] for multiple nodes and gateways. The SGW (Serving Gateway) routes data packets through the access network. The PGW (Packet Gateway) provides connection of EPC elements to the Internet and possibly other data networks. The PCC is divided into the PCRF and the PCEF (Policy and Charging Enforcement Function) working as decision taker and applier, respectively [4][5]. Generally, PCRF takes its policy and QoS decisions based on the information received from the AF (Application Function). This latter notifies PCRF the QoS requirements initiated by a UE (User Equipment). PCRF also consults SPR (Subscription Profile Repository) to check whether the corresponding user has rights to access the required QoS treatment. It then authorizes the desired QoS resources based on QCI (QoS Class Identifier), ARP (Allocation and Retention Function) and GBR/MBR (Guaranteed/Maximum Bit Rate) and transfers this information to PCEF (located in PGW) which performs policy enforcement and charging functions.

The access network, the E-UTRAN is made of the UE and the eNodeBs (or the LTE base stations). This eNodeB is the concatenation of NodeB and RNC (Radio Network Controller) of the previous UMTS (Universal Mobile Telecommunications System) architecture.

The EPS/LTE can be viewed as an IP radio connectivity provider between an external data network, known as the PDN (Packet Data Network), often the Internet, and the LTE terminal. The EPS bearers often called "bearers" (e.g., bearers S1, S5/S8, etc., in Figure 1) are the data flows defined between the UE and the PGW with specified QoS. Two types of EPS bearers are defined. The default bearer: the bearer, established when the terminal connects to a PDN, there is then one default bearer for each PDN connection. The default bearer is the Best Effort (BE). The dedicated bearers are all additional bearers that can be established in each PDN connection. These bearers, (e.g., a voice call bearer) have QoS guarantees [19].

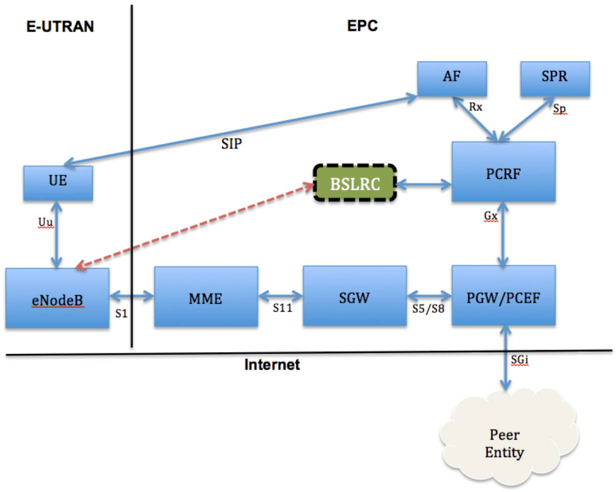

Figure 1. LTE architecture with possible placement of BSLRC

III. AN ESTIMATION OF SIGNALING LOAD FOR BSLRC

This section presents an estimation of signaling load between the eNodeBs and the BSLRC. This latter was proposed in [1] as an additional database associated with the PCRF to optimize its radio resource assignment policy. In its first version, the BSLRC (see Figure 1 and Table 1) contains the IDs of eNodeBs, the percentage of PRBs used and the observed MCS order. To realize the operator policy, the PCRF takes its policy decisions by consulting the information provided in BSLRC. However, for the BSLRC to stay updated, frequent information must be exchanged between itself and the related eNodeB resulting in some additional signaling load. Therefore, here we provide some hypothetical values to measure this signaling load between BSLRC and eNodeBs.

Table 1. An example illustration of BSLRC with some supposed values

ID of eNodeB	%tage of PRBs used	MCS order observed
5	56	9
8	77	16
11	25	24

Expected signaling load

We denote BS_N as the number of eNodeBs, $signaling_n$ as the number of signaling updates per second (/s) for each eNodeB, M as the total signaling messages exchanged between the BSLRC and its related BS_N, *R(send)* and *R(rec)* as the sending and receiving signaling rates calculated in Mbps associated to all M. We also denote that each eNodeB has a maximum of 25 PRBs (considering a 5MHz cell) and for a single signaling update two messages are exchanged with *R(send)* of 0.078 Mbps and *R(rec)* of 0.048 Mbps per eNodeB, respectively[1]. Thus, for a signaling update, a total of approximately 0.126 Mbps of load is moved between the BSLRC and its eNodeB. Note that several events can cause the exchange of signaling information between LTE network elements. These events may be in the form of connection/disconnection of a UE, its spatial or temporal location change, renewing of users rights based on their QoS authorizations and their resource modification requests, etc. Further details about the event triggers can be found in [10]. Moreover, in this paper, we estimate the values for one BSLRC associated to several eNodeBs, however these estimations can easily be performed for more than one BSLRC.

Based on above, we have calculated the values of M, *R(send)*, and *R(rec)* considering different $signaling_n$ for several BS_N and a few are shown in Table 2[2]. Some values are also plotted in Figures 2(a) and 2(b) which clarify that M and *R(send)* are the increasing functions of $signaling_n$ i.e. the higher the signaling rate, larger the load on LTE network elements. This pattern is explained as follows: When the $signaling_n$ is low (let us suppose 2/s), less amount of signaling load is exchanged between the eNodeB and the BSLRC. When the event triggering is high, for instance let us suppose that the users are moving very frequently, they require more resource authorizations and modifications and so on, then the values of $signaling_n$ can remain at a larger level (e.g., 100/s considering a highly mobile scenario). This causes an increment in message exchange and thus augmenting the overall signaling load.

Table 2. Signaling load for several eNodeBs

BS_N	1	2	5	10	100	500
When $Signaling_n$ = 2/s						
M	4	8	20	40	400	2000
R(send) Mbps	0.15	0.31	0.78	1.56	15.62	78.12
R(rec) Mbps	0.097	0.19	0.48	0.97	9.76	48.82
………… …………						
When $Signaling_n$ = 100/s						
M	200	400	1000	2000	20000	100000
R(send) Mbps	7.81	15.62	39.06	78.12	781.25	3906.25
R(rec) Mbps	4.88	9.76	24.41	48.82	488.28	2441.40

[1] These values of *R(send)* and *R(rec)* are obtained by performing small level experiments in MATLAB.

[2] For more than 500 eNodeBs and higher signaling rates, the values of M, *R(send)*, and *R(rec)* can be calculated following the similar pattern.

IV. COMPARISON BETWEEN ECN AND BSLRC

In this section, we compare the BSLRC [1] and the ECN (already included under LTE framework [13] and analyzed in [12][17]). As specified before, the role of PCRF is to take policy decisions based on available QoS requirements initiated by the user and the amount of available resources. Generally, PCRF can access the QoS requirements of users and their access rights in the AF and SPR modules, respectively. However, to provide PCRF with a radio efficient decision policy for operators, a database such as BSLRC can be used. By consulting BSLRC, the PCRF can check the recent status of eNodeBs and their related PRBs, to make a radio efficient decision. On the other hand, with ECN, the senders obtain feedback on the congestion caused by their routed traffic and this information is later used by the Base Station (BS) to control and regulate network traffic. Then, in order to optimize its decision policy, the PCRF can acquire the network congestion information by interacting with the ECN-policer [17] that can be located at the BS to manage user specific data e.g., the accounting and cost information. In fact, both BSLRC and ECN share the same objective to optimize the choice of codec rate with regard to radio use efficiency. Therefore, a clear comparison is mandatory between BSLRC and ECN to see their pros and cons, which is provided in this Section.

(a) (b)

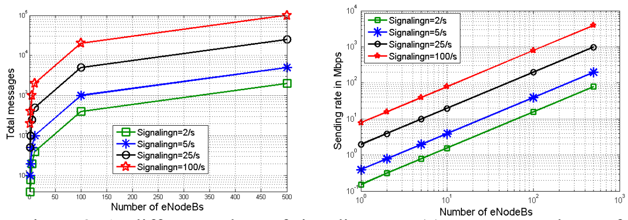

Figure 2. At different values of signaling rate, (a) Message exchange for several eNodeBs, (b) Sending rate for various eNodeBs

A. Pros and cons of ECN

When ECN method is used, the eNodeB notifies its sender and receiver about the network congestion so that the packet transmission rate can be reduced. Basically, the ECN contains a two bit (or a 4-combinational) field in IP header which is subdivided into ECT (ECN Capable Transport) and CE (Congestion Experienced). The former is set by the eNodeB to indicate that its senders and receivers are ECN-capable. The latter is also set by the eNodeB to notify congestion in the route in which packets are being sent. This notification process avoids unnecessary packet drops and there are less retransmissions which can result in improvement of overall “goodput”. Moreover, compared to other non-ECN flows where at least 3 acknowledgements are exchanged to signal the congestion [16], ECN notifies congestion in the first acknowledgement. These smaller transmissions can significantly reduce the network traffic.

Though ECN seems an interesting mechanism to increase network capacity by reducing the congestion, it has a few drawbacks. For example, to interpret the meaning of ECN bits (i.e. ECT and CE), additional functionalities must be added in sender and receiver and it would be difficult to update, in this sense, all the network terminals in order to be used with ECN.

Another issue is related to the adjustment of ECN in LTE networks i.e. how to integrate ECN within LTE network elements so that the PCRF can directly access it? In general, integrating ECN with LTE networks seems to be a complex task as it requires interfacing with LTE network elements. Even if we make some LTE elements (such as eNodeBs, UEs, gateways) ECN capable, still it will require a few tunneling protocols to be specified in order to perform the packet transfer. For example, the ECN-policer specified in [17] can be consulted by the PCRF as it is placed in the PCEF, but the questions of how the PCEF will be adapted with this architectural change and are there some special bearers to be defined in order to provide PCRF interaction with ECN-policer, still remain unanswered. Another difficulty for ECN to work within mobile networks is the fact that an operator might use different vendors for the core and EUTRAN networks and some of these vendors might not support ECN.

B. Pros and cons of BSLRC

In LTE systems, PCRF needs to have general information about the current network traffic (e.g., the load on the nearby eNodeBs) to better make its decisions. Thus, in order to stay updated, the PCRF can consult BSLRC in order to check the status information of the nearby eNodeBs in terms of their percentage PRB usage and MCS order. As was shown in Figure 1, BSLRC can easily be added in the LTE network without modifying the internal architecture of any LTE element, therefore no additional interfacing with network is required. Further, because there is no congestion notification, the LTE network elements do not require quick adaptations to certain variations in transmission rates, as it was the case with ECN. In fact, all the elements can continue functioning in their traditional way and whenever resource congestion occurs, the eNodeBs can update their BSLRC, which is then frequently consulted by PCRF to take the necessary measures. The expected advantage of using BSLRC in conjunction with the eNodeBs and the PCRF is a better use of radio resources with high income for the concerned operators.

Beside above (and as shown in Section III), BSLRC requires some additional signaling information or load to be exchanged between LTE network elements. This information exchange increases as more events are triggered within the network, thus by increasing the overall network load. Therefore, it would be interesting to measure the signaling load caused by ECN and compare it with that of BSLRC. For example, one can calculate the number of ECN notifications exchanged during network congestion as well as due to the occurrence of an event and then, these notifications can be compared with those of BSLRC based on similar values of parameters i.e. number of eNodes, sending and receiving rates, and so on. We leave this as a part of our future work.

Another important concern is how often does the PCRF consult BSLRC? This is also common for the ECN supported LTE environments and several strategies can be developed to make a viable PCRF consulting strategy. For example, PCRF can consult BSLRC after a fixed interval to update its view about the radio network load. In this case, this specified interval must be defined based on the LTE architectural concerns. Another PCRF policy would be to refer to BSLRC at the occurrence of every event trigger requiring PCRF to react sharply. Here, an optimal policy would be to prioritize the events and then allowing PCRF to consult BSLRC at the occurrence of only high priority events. Let us say for instance, the PCRF can consult the BSLRC at the arrival of gold or silver members in order to better serve their QoS and resource allocation requests and so forth. Moreover, like ECN, the bearers are not yet specified for the BSLRC but the bearers *S7* and *Sdb* proposed in [11] can be used.

We summarize the important points for BSLRC and ECN in Table 3. Note that for this table, we refer to the standard ECN presented in [12] and its possible placement in LTE networks as proposed in [17], under the same title "ECN adaptation". From the table, it is clearly visible that BSLRC and ECN are targeted towards increasing radio resource usage in LTE systems while having interactions with PCRF and certain LTE elements (such as eNodeBs). Both these solutions can incur signaling load however for ECN this load is yet to be measured.

Table 3. Some common points between BSLRC and ECN adaptation

Properties	BSLRC	ECN adaptation
Radio resource management	Yes	Yes
Interaction with PCRF	Yes	Yes (but yet to be defined)
Bits specified in IP header	No	Yes (two bits: ECT, ECN capable transport and CE, congestion experienced)
Congestion control	No	Yes
Method of resolution	Mostly proactive	Reactive
Probable placement in LTE architecture	Yes (see Figure 1)	Yes (refer to [17])
Additional signaling load	Yes (calculated in Section III)	Yes (but yet to be calculated)
Special tunneling protocols	No	Yes (e.g., proxy mobile IP)
Scaling issues	Yes	Yes

BSLRC is more of a proactive approach, where the PCRF has to frequently consult it in order to see the status of the eNodeBs and their radio resources. ECN is rather reactive where the related LTE network elements react at the occurrence of congestion. The potential advantage of BSLRC over ECN is its easy adjustment within network without adding any additional functionality to LTE network elements. In addition, the PCRF will perform more accurate and cost-effective decisions based on the updated knowledge received from the BSLRC which will result in high incomes for the operators. However, when the environment is highly dynamic and critical (i.e. not even a small amount of packets can be dropped), then ECN may be preferred over BSLRC to handle network congestion.

V. CAPACITY ESTIMATIONS FOR MULTIMEDIA ENVIRONMENT

In this section, we provide some capacity estimations for an eNodeB in order to support video services (such as video calls, multimedia streaming, etc.) to its users and try to graphically adjust these estimations with those proposed for voice services in our previous work [1]. These estimations are derived based on the information provided in [20][21].

A. Video capacity of an eNodeB for a 5MHz cell

The video streams are divided into frames where each frame consists of 8 packets. Each video packet has a size of 100 Bytes which gives a total frame size of 800 Bytes (i.e. 8×100). The video frame is then transmitted after every 100ms, thus the physical data rate for each video frame/100ms is 62 Kbps (800 Bytes/100ms). Knowing the physical data rate, we can easily compute the data size to be transmitted/100ms as shown in Table 4 and we consider this as the video sampling rate for the GBR (Guaranteed Bit Rate). Likewise, the sampling rate for MBR (Maximum Bit Rate) can be calculated and it is depicted in Table 4.

The next step is to check for the preferable modulation and coding schemes (or MCSs). These MCSs can easily be verified if we know the channel qualities of downlink i.e. the SIR (Signal-to-Interference Ratio) [22]. Based on these channel qualities and their associated MCSs, we can foresee the proportion of UEs as shown in Table 5. Note that, the SIR values for the UEs are not uniform, therefore a cell can use several combinations of these MCSs (or probably all of them) in order to send packets to its UEs.

Table 4. Data size for GBR and MBR

Video rate	Data rate in Kbps	Size of data/100ms
GBR	62	6200 bits
MBR	156	15600 bits

Now we extend Table 5 to some more useful factors. Each MCS has a corresponding MCS index, while this MCS index is then mapped to its TBS (Transport Block Size) index. These indexes help us to find the number of PRBs necessary to send the payload and they are derived from the Tables 7.1.7.1-7 and 7.1.7.2.1-1 of [20] and from [23]. The relative number of PRBs necessary to send the total payload for GBR and MBR are also expressed in Table 5 (taken by thoroughly observing the data provided in [20]). Note that for simplicity, this table represents SIR values ≤18, nonetheless similar pattern can be used to map higher than 18 SIR values to their MCS and TBS indexes.

For instance, in a 5MHz cell let us take an example of an SIR range 12.7 to 16.9 for which the MCS and TBS indexes are 16 and 15, respectively. For the GBR, if the payload to send is 6200 bits, then 20 PRBs can carry this load. The PRBs for other SIR ranges are calculated in similar fashion. Then, the capacity of an eNodeB can be calculated from the total PRB usage. For example, in GBR, 0.11 of the UEs use 50 PRBs, 0.10 use 39 PRBs, 0.25 use 24 PRBs, 0.21 use 20 PRBs, 0.04 use 14 PRBs and 0.26 use 12 PRBs, thus the average number of PRBs per user in a cell is 23.28 (or 0.2328 because the packets are sent every 100ms). Similarly for MBR, the average number of PRBs in a cell is 44.76 (or 0.4476). Now, knowing that a 5MHz cell has a maximum of 25 PRBs [4], we get the total number of UEs that can be served as 107 and 56 for GBR and MBR, respectively. Therefore, it is clear that an eNodeB may serve up to 107 and 56 UEs in a 5MHz cell in order to provide the guaranteed and maximum bitrates to its users.

B. Video, voice and best effort adjustments

So far, we have estimated the capacity for an eNodeB over a 5MHz cell for video services, however the user traffic is always the mixture of video, voice, and BE (or FTP) services. Therefore, we provide a simple adjustment of these services over a 5MHz cell based on the above calculations and those performed in [1] (for voice services). For BE, we always assume a 10% reservation of bandwidth (i.e. 3 PRBs) [21]. As a result, in the following, a plot for other 90% of bandwidth (reserved for voice and video) services is shown and the case of GBR is considered.

Figure 3 shows number of served UEs for voice and video services where the maximum number of PRBs in a 5MHz cell is 22. In this figure, if *N* denotes the PRBs for voice, then 22-*N* would be the PRBs reserved for video users. It is clear that more UEs are served for video considering small *N* and vice versa. Another observation is that the number of served UEs for voice are much larger than video UEs. This is obvious because the voice packets are transferred every 20ms and they have the payloads of 200 bits for GBR. As a result, the voice users acquire less capacity compared to video users.

A possible extension of this work is the choice of an optimize QoS charging policy for the multimedia environment. The PCRF can make this choice with regard to the operator revenue by giving priority to the prestigious (or "gold") users when a eNodeB is highly-loaded. Estimation of such a revenue increase should allow the fine-tuning of this pricing scheme. We consider it in our future research work.

VI. CONCLUSION

In this paper, we have focused on explaining and comparing policy realization strategies within LTE networks where the QoS implementation model can be used for different studies, the central element of which is the PCRF. Basically, this work is an extension of our previous paper where we have added a new element named as BSLRC within LTE framework, containing information about the eNodeBs load and their MCS order. BSLRC can then be consulted by the PCRF whenever needed for policy decisions. We have also calculated the signaling load `between BSLRC and the corresponding eNodeBs and it is

Table 5. Corresponding PRBs based on SIR ranges, MCS and TBS indexes [1]

SIR range	Corres-ponding MCS	MCS index	TBS index	Proportion of UEs	PRBs for GBR (6200 bits/100ms)	PRBs for MBR (15600 bits/100ms)
0 ≤ SIR < 2.9	Outage	N/A	N/A	0.03	Outage	Outage
2.9 ≤ SIR < 6.3	QPSK 1/2	7	7	0.11	50	N/A
6.3 ≤ SIR < 8.6	QPSK 3/4	9	9	0.10	39	99
8.6 ≤ SIR < 12.7	16QAM 1/2	14	13	0.25	24	61
12.7 ≤ SIR < 16.9	16QAM 3/4	16	15	0.21	20	51
16.9 ≤ SIR < 18	64QAM 2/3	22	20	0.04	14	34
18 ≤ SIR	64QAM 3/4	24	22	0.26	12	29

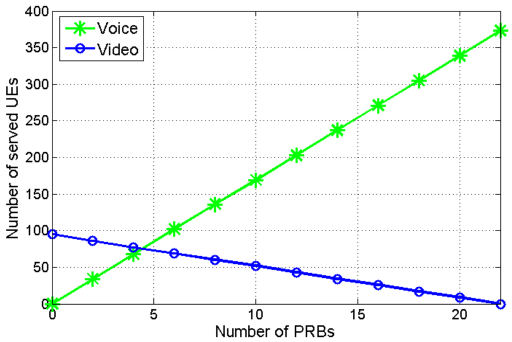

Figure 3[3]. Number of served PRBs for voice and video considering a 5MHz cell

clear that this load remains higher when the number of signaling updates is very frequent. Then, we have compared BSLRC with ECN highlighting various important and novel aspects. Later, after some capacity estimations for the video services, we consider a simple allocation proposal. This research work should be valid for any open access OFDMA wireless network such as WiMAX.

In our work, we do not address the signaling delays and the scalability issues related to BSLRC which should be kept in consideration as future perspectives. Moreover, it would be interesting to measure the signaling load associated with the ECN and compared it with that of BSLRC. We do not address the realization considerations in this theoretical work. This work is then just a research proposal trying to identify amelioration possibilities before more practical considerations that can be left as a future issue of research. The extension of this work to include RRM (radio resource management) features such as admission control is another interesting perspective.

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