4.5G Capacity & QoS Optimization: A New Proposal to Enhance the Principal KPIs of 5G/IoT

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Abstract—RF capacity management and optimization is an important part of the network performances of the future. Technically, 4.5G/5G mobile network is expected to enable people-thing and thing-thing interconnections by combining communication technologies and networks. Our Lab has been actively promoting research on 4G & 5G performances, in which the RF Capacity management issue is of great interest. New 4G/5G tests put forward a lot of requirements for RF network performances in terms of KPIs, QoS, as well as user experience. Based on Morocco's current situation, this article first discusses the LTE cell resources monitoring and optimization, Furthermore, we will introduce LTE OMSTAR tool, and LTE cell resources optimization scenarios are summarized.

Keywords— LTE Capacity, RF Optimization, 5G, QoS, IoT.

1 Introduction

With the rapid development of smart terminals and services the impact of capacity problems on KPIs and User experience increased, therefore close monitoring for Key bottleneck of LTE resources is required to ensure better KPIs and user experience.

Capacity monitoring can be implemented using the following two methods: [1]

- Daily monitoring for prediction: Counters are used to indicate the load or usage of various types of resources on the LTE network. Thresholds for resource consumption are specified so that preventive measures such as reconfiguration and expansion can be taken to prevent network congestion when the consumption of a type of resource continually exceeds the threshold. [2]
- Problem-driven analysis: This method helps identify whether a problem indicated by counters is caused by network congestion through in-depth analysis. With this method, problems can be precisely located so that users can work out a proper network optimization and expansion solution.

LTE Resources are:

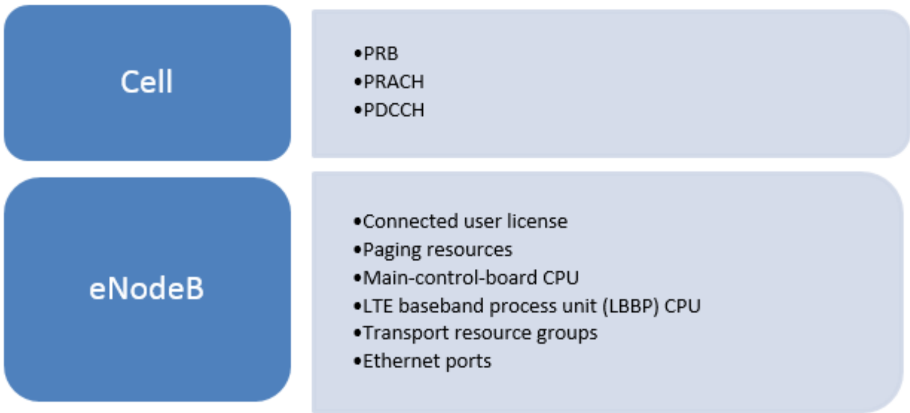

Fig. 1. LTE cell and eNodeB resources.

This paper concentrates on LTE Cell Resources.

2 PRB: Physical Resource Block

Resource Block is the minimum unit for resource allocation used for data transmission in physical layer, it consists of two dimensional domain: [3]

- Time Domain: 1 Slot= 7 OFDM Symbol (normal CP).
- Frequency Domain: 12 Subcarriers.

RB number depend on the LTE system bandwidth as shown in table 1

Table 1. RB number vs LTE system bandwidth.

Channel bandwidth $BW_{Channel}$ [MHz]	1	3	5	10	15	20
Sub-carriers Number	72	180	300	600	900	1200
RB Number	6	15	25	50	75	100

2.1 Resource Element (RE)

Smallest unit in PRB consist of two dimensional domain:

- Time Domain: 1 OFDM Symbol.
- Frequency Domain: 1 Subcarriers.

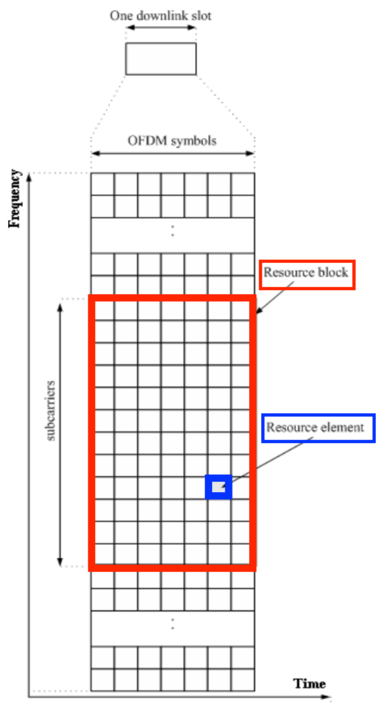

Fig. 2. LTE resource element.

2.2 Usage Increase by

- As Data traffic growth PRB Usage increases.
- As PRB Usage reaches 100%, user perceived traffic will decrease.

2.3 Insufficiency

- Growing traffic leads to a continuous increase in PRB usage. When the PRB usage approaches to 100%, user-perceived rates will decrease as follow:
  - New Users may fail to be admitted
  - Admitted users experience is affected.

2.4 Monitoring

- Downlink PRB usage = L.ChMeas.PRB.DL.Used.Avg/L.ChMeas.PRB.DL.Avail x 100%
  - L.ChMeas.PRB.DL.Used.Avg = Average used DL PRBs
  - L.ChMeas.PRB.DL.Avail = Available DL PRBs
- Downlink user-perceived rate (Mbit/s) = L.Thrp.bits.DL/L.Thrp.Time.DL/1000
  - L.Thrp.bits.DL = DL PDCP Layer Throughput

- L.Thrp.Time.DL= duration for transmitting DL PDCP layer data

2.5 Root Cause Analysis/Solution

- Factors affecting PRB usage:
  - Poor Channel Quality
  - Parameter Settings
  - User number
  - Traffic Model ”service requirement of each user”
- PRB Limitation leads to prolong UE Scheduling delay → decreasing UE Data Rate.

2.6 Poor Channel Quality

- Lead to low spectrum efficiency and increase PRB usage.
- DL Spectrum Efficiency = L.Thrp.bits.DL/L.ChMeas.PRB.DL.Used.Avg/ (rep rt Period*60)/180000 “bit/s/Hz”
- If Less than 1bit/s/Hz → Optimize RF Quality
- UL Spectrum Efficiency = L.Thrp.bits.UL/L.ChMeas.PRB.UL.Used.Avg/ (report Period*60)/180000 “bit/s/Hz”
- If Less than 0.5bit/s/Hz → Optimize RF Quality

2.7 Parameter Settings

- DL
  - RbgAllocStrategy=Adaptive
  - If the number of required RBs is less than that of one RBG, RBs are allocated to the scheduled UE as required, which is specified by resource allocation type 1.
  - If the number of required RBs is greater than that of one RBG, the number of allocated RBGs is rounded up and an integral number of RBGs are allocated to the scheduled UE. Compared with RBG round-up, this mode prevents RB waste when the number of required RBs is less than that of one RBG
- UL
  - UlSchSwitch=PuschDtxSwitch-1
  - During UL transmission if UE fail to detect UL GRANT or SR false alarm appear in DRX state
  - Enabled:UE will report(ACK/NACK/DTX) if the HARQ feedback state of one uplink schedule is DTX, eNodeB will deliver UL GRANT again instead of starting HARQ retransmission. If the next HARQ feedback is still DTX, eNodeB will stop the schedule triggered by this SR
  - Disabled:lead to the uplink retransmission repeatedly and waste the uplink PUSCH resource and the uplink error code rate will increase obviously.

2.8 User Number

- If average RRC_Connected User(L.Traffic.User.Avg) >300
  - Downlink user-perceived rate < a user-defined threshold (default value: 2 Mbit/s)
- Resource Insufficiency cause the low Data Rate→ Consider Expansion
- Formula for Downlink user perceived rate:
  - Average DL Throughput for single User = (L.Thrp.bits.DLL.Thrp.bits.DL.LastTTI)/L.Thrp.Time.DL.RmvLastTTI*1000

2.9 Threshold for Expansion

- Add carriers or eNodeBs if both of the following conditions are met:
  - Downlink PRB usage ≥ 70%
  - Downlink user-perceived rate < a user-defined threshold (default value: 2 Mbit/s)

2.10 OMSTAR Analysis: Operation & Maintenance

- Whole Network PRB Analysis
- PRB Resource Usage Distribution
- Uplink/Downlink PRB Resource Usage Distribution (RRU)
- The Cell List of Uplink/Downlink PRB Resource Usage Over Threshold
- PRB Resource Usage(Daily)(Cell/Busy Hour)(Network/Busy Hour)

2.11 UL / DL Formulas

- Uplink PRB resource usage = Average number of uplink PRBs scheduled in each second
- (L.ChMeas.PRB.UL.Used.Avg+ L.ChMeas.PRB.PUCCH.Avg)/ Total number of uplink PRBs in a cell x 100%
- Downlink PRB resource usage = Average number of downlink PRBs scheduled in each second
- (L.ChMeas.PRB.DL.Used.Avg)/ Total number of downlink PRBs in a cell x 100%

2.12 OMSTAR Threshold is

- OMSTAR threshold for Expansion is 70% PRB usage.

Table 2. PRB cell usage KPIs.

Time	*Whole Network Average Number of Uplink Used PRB per Cell*	*Whole Network Average Number of Downlink Used PRB per Cell*	*Whole Network Average Uplink PRB Resource Usage per Cell*	*Whole Network Average Downlink PRB Resource Usage per Cell*
x	*4.33*	*4.85*	*8.65%*	*9.71%*

2.13 For Low Spectral Efficiency

DL (1bPs/Hz):
Check if MCS <10 or CQI<6 → RF Issues → otherwise Check MIMO Setting
UL (0.5 bps/HZ):
Check if MCS<10 or SINR<5 → RF Issues
Downlink/Uplink Spectral Efficiency (Daily) (Cell/BH) (Network/BH)

3 PRACH: Physical Random Access CHannel

Random access is performed in the following scenarios: [3]

1. Initial RRC connection setup to switch from the RRC_IDLE state to the RRC_CONNECTED state, a UE initiates random access.
2. RRC connection reestablishment When a radio link failure (RLF) occurs, the UE needs to reestablish an RRC connection. In this scenario, the UE initiates random access.
3. Handover During a handover, a UE initiates random access in the target cell.
4. Downlink data arrival when an eNodeB needs to send downlink data to a UE in the RRC_CONNECTED state and finds that the UE is out of uplink synchronization, the eNodeB instructs the UE to initiate random access.
5. Uplink data arrival When a UE in the RRC_CONNECTED state needs to send up-link data to an eNodeB and finds that it is out of uplink synchronization, the UE initiates random access.
6. LCS When a location service (LCS) is required, the eNodeB initiates random access.

3.1 Random Access message

As shown in below figure consist of

- CP ”Cyclic prefix”
- preamble sequence
- Guard period

Since Random Access message is first message sent from UE side and the TA “Time advance” is not known yet, so guard period is used to ensure message arrival is within the TS.

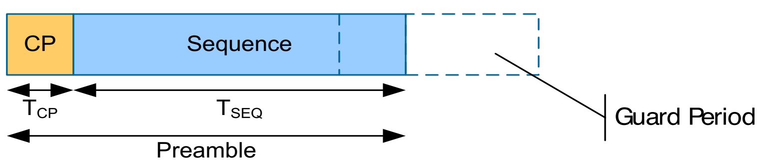

Fig. 3. Random Access message

3.2 Usage Increase by

- Access requests (initial- UL/DL Data).
- Handover times.
- LCS
- RRC connection reestablishment.

3.3 Root Cause analysis/Solution

Enable Random Access Backoff. The RACH does not interfere with other uplink channels in LTE. Generally, the probability of RACH conflicts is low.

If excessive UEs are admitted on a PRACH, however, preamble conflicts may occur, and some UEs may fail to access the network. To solve this problem, random access backoff is introduced to control the time for preamble retransmission by UEs. [4]

If random access backoff is enabled, the eNodeB notifies a UE of a backoff value in the random access response message. When the UE needs to retransmit a preamble, it randomly selects a value (from 0 to the received backoff value) as its backoff time. The UE can retransmit the preamble only after the backoff time ends.

Random access backoff is not performed in the following two scenarios:

- Initial preamble transmission
- Preamble retransmission in non-contention-based random access

When to use?

If the random preamble usage reaches or exceeds 75% for three days by default in a week, enable the adaptive backoff function.

PRACH resource adjustment algorithm. In case of Preambles are insufficient PRACH resource adjustment algorithm acts as follow:

If dedicated preambles are in surplus and random preambles are insufficient, the eNodeB reduces the number of dedicated preambles.

If dedicated preambles are insufficient, the eNodeB increases the number of dedicated preambles.

Whether dedicated preambles are insufficient is measured based on the dedicated preamble allocation failure rate, which is equal to one minus the ratio of the number of UEs that are allocated dedicated preambles to the number of UEs that apply for dedicated preambles.

MaksIdxSwitch: Indicates the switch used to control reuse of dedicated preambles between UEs. If the switch is on, the eNodeB enables reuse of dedicated preambles among UEs based on the MaskIndex parameter. If the switch is off, the eNodeB allocates a dedicated preamble to only one UE at a time.

When to use?

If the dedicated preamble usage reaches or exceeds 75% for X days (three days by default) in a week, enable the PRACH resource adjustment algorithm and reuse of dedicated preambles between UEs.

This helps reduce the probability of UEs initiating contention-based random access in the case of dedicated preamble insufficiency and therefore helps reduce the access delay.

Threshold for Expansion. If above actions implemented and the resource usage is still >75% add eNodeB or split Cell.

4 Profit from LTE RF Capacity Management and Optimization

By monitoring, managing and optimizing LTE Capacity you can:

- Avoid Access Failure
- Improve UE Experience and main 4G/4.5G/5G KPIs
- Decrease Handover Delay
- Decrease Uplink and downlink scheduling delays.

5 Conclusion

This paper provides an overview of LTE capacity optimization steps and provide a new approach for 4.5G/5G three main KPIs improvement (massive connections, low latency and high throughput).This article discusses also RF optimization solutions of LTE cell resource. Our analysis results by OMSTAR Tool show that the targets can be achieved in all LTE expansion scenarios to 4.5G and 5G/IoT.

6 Acknowledgment

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