LTE MOBILE NETWORK OPTIMIZATION

A definitive guide

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ROHDE&SCHWARZ

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CONTENTS

LTE provides global mobility with a wide range of services that includes voice, data and video in a mobile environment with lower deployment costs. Mobile networks are rapidly transforming (traffic growth, increased bit rates per user etc.) due to new technologies such as LTE. The growth in mobile traffic is mainly driven by devices such as smartphones and tablets. To get the best performance out of an LTE network, it needs to be optimized continuously. This white paper examines wireless network optimization challenges from a radio network perspective. Key performance indicators (KPI), performance indicators (PI), field measurement metrics and parameters are described in their context.

1 INTRODUCTION

Regardless of the domain (radio or core) and technology, optimization should be seen as a set of processes and activities that analyze the system and then elaborate and recommend actions to make sure the system operates efficiently and performs well. Optimization is a broad term, and in cellular networks it covers both pre-optimization and post-optimization before and after the network is built and in operation. The outcome of network optimization and the network optimization workloads are directly related to future network capacity and stability. Optimization usually looks at coverage, interference, mobility, capacity and quality.

In general, the network optimization process should analyze access, session drop, latency, mobility, congestion, paging and other factors. Commercially, vendors offer optimization as two separate services: the initial tuning or pre-launch optimization and the post-launch optimization. Conventionally, cellular network optimization solutions are divided as follows:
- Performance statistics
- Performance recording
- Performance data analysis

The goal of optimization is to maximize the operator's investment and end-user satisfaction. Performance engineers need to know how a system works, including the basic procedures from the moment a phone is turned on and a call/data session is started to when the user hangs up, along with what might occur in between and the potential influences on each process.

Engineers also need to know how the system is performing. System performance is based on specific data collection tools, KPIs, etc. A performance engineer should then be able to evaluate network performance based on KPIs and propose recommendations and solutions to optimize the network. With operators reducing OPEX (and expertise in network optimization), demand is growing for smart tools that support more automated network insights based on collected data.

2 OPTIMIZATION

2.1 Quality of the network versus QoE

Mobile networks are highly complex structures, intricately designed to meet the quality requirements of the network and subscribers. To subscribers, the labyrinthine design of a mobile network seems transparent and straightforward; either they have the expected service quality or not – whether making a call, watching a video or posting on social media.

Subscribers equate network quality of service (QoS) such as voice or video quality with quality of experience (QoE), which is influenced by the device and content. Regardless of whether a mobile network operator (MNO) or a third-party content provider controls the service. So, where does this leave MNOs that want to ensure end-user QoE and optimize their network and services? What do they need to consider before investing in a mobile network testing solution?

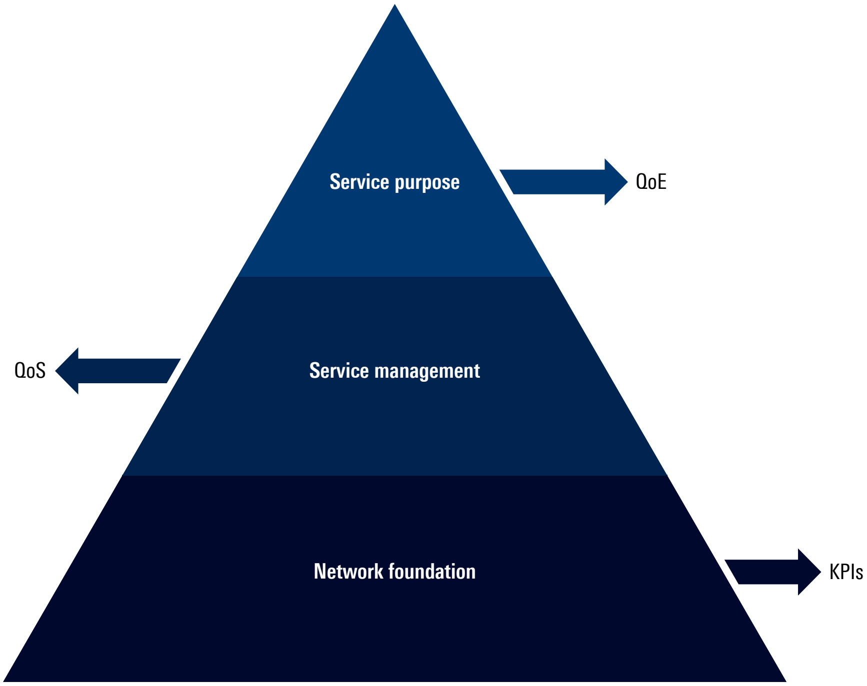
The goal of the MNO is superior end-user QoE. The MNO may lose subscribers if a competitor has a better QoE. Third-party user equipment (UE), such as smartphones, connect to the MNO and influence the QoE, but operators have limited control. The MNO controls the servers for its voice and video services. Subscribers also use applications from third parties or over the top (OTT) media services. Typically, an application client located on a smartphone connects to an application server that is beyond the control of the MNO. The MNO has no direct control over third-party applications such as YouTube or Spotify. Different tests are required to test network quality and QoE.

The ultimate purpose of optimization is to provide continuous and reliable service as well as to make sure end users are satisfied with the service. End-user experience metrics such as the voice mean opinion score (MOS) are not the same as the QoS metrics such as bit error rate (BER). Performance engineers are often confused about the difference between QoS, QoE and optimization. QoE is the customers perception of how well a service is delivered. End-user perceptions of overall quality depend upon multiple aspects of the network and service. QoE is directly affected by QoS, but it is different.

QoS focuses on measuring performance at the packet level from the network perspective and is measured objectively while QoE is subjective and needs to be translated into quantitative data. It is possible to have excellent QoS but poor QoE. In general, end users do not care how a network is implemented and the QoS. They just want better QoE.

In order to understand how QoS influences QoE, a performance engineer must look at more than the raw KPIs. Optimization engineers need to know about perceived quality. Efficient utilization of overall network data to analyze and optimize network quality is another challenge for performance specialists. The graphic below explains the relationship between QoS, QoE and KPIs.

Fig. 1: Relationship between QoE, QoS and KPIs

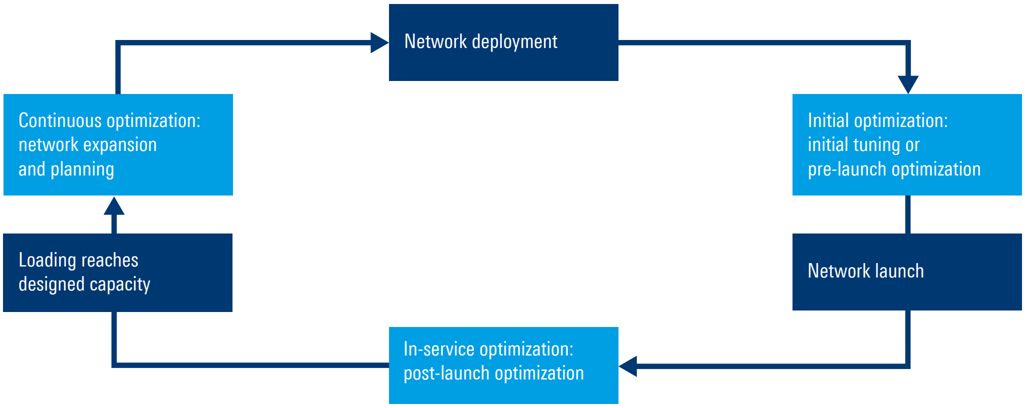


2.2 LTE optimization

Optimizing LTE networks mainly refers to pre-optimization before a network launch and continuous optimization afterwards. Network optimization is a continuous task and is necessary for network performance to meet certain thresholds or KPIs agreed by the operator. After a network is deployed and before it is on air, pre-launch optimization is needed. Changes during pre-launch optimization are mainly physical (e.g. antenna tilts and azimuths), although they may also include some parameter changes to optimize network coverage and quality. Since there is very little or no traffic on the network counters, they cannot provide statistically reliable information. Drive and walk tests are mainly used to optimize the network during the pre-launch to obtain certain field KPIs.

Once launched, the network traffic volume and its nature changes continuously, so optimization is still needed to maintain the high level of performance defined by KPIs. In general, pre-launch optimization focuses on coarse tuning of the network and post-launch optimization focuses on the fine tuning of the network.

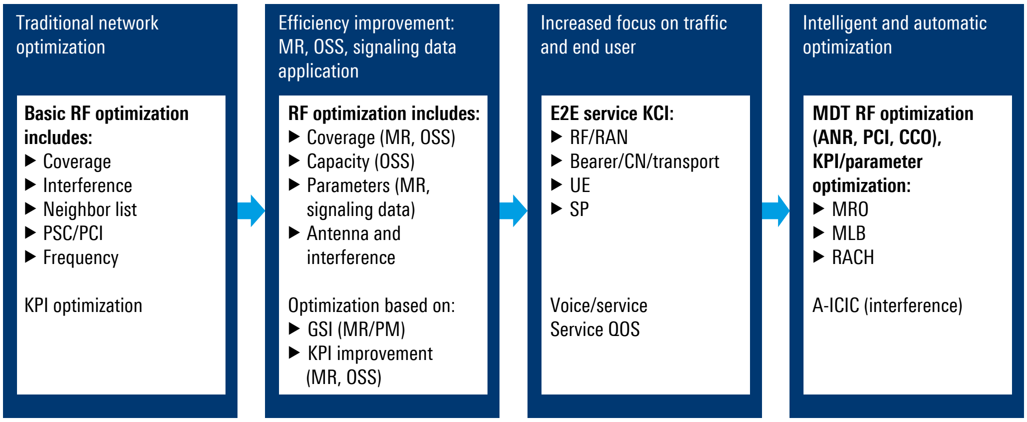
Fig. 2: Pre- and post-launch optimization workflow



2.3 How optimization has evolved

Operators are always looking for different ways to automate networks with fewer manually-controlled parameters to reduce operational costs while delivering a more seamless connection and making the network more intelligent. In this context, self-organizing networks have emerged as a set of use cases based on network generated data that cover the entire network lifecycle – from planning and deployment to operation and optimization. The goal of self-optimization is the automatic fine tuning of initial parameters for improved cell/cluster performance and dynamically recalculating these parameters if the network, service and traffic change. The technological evolution of optimization is shown in detail in Fig. 3. Please note that optimization is not yet fully automated. Operators are reluctant to delegate the authority to change fundamental network parameters to automatic algorithms and artificial intelligence because of concerns about creating instability.

Fig. 3: How optimization has evolved



Traditional network optimization

Basic RF optimization includes:
- Coverage
- Interference
- Neighbor list
- PSC/PCI
- Frequency

KPI optimization

Efficiency improvement: MR, OSS, signaling data application

RF optimization includes:
- Coverage (MR, OSS)
- Capacity (OSS)
- Parameters (MR, signaling data)
- Antenna and interference

Optimization based on:
- GSI (MR/PM)
- KPI improvement (MR, OSS)

Increased focus on traffic and end user

E2E service KCI:
- RF/RAN
- Bearer/CN/transport
- UE
- SP

Voice/service
Service QOS

Intelligent and automatic optimization

MDT RF optimization (ANR, PCI, CCO), KPI/parameter optimization:
- MRO
- MLB
- RACH

A-ICIC (interference)

3 LTE SYSTEM ARCHITECTURE

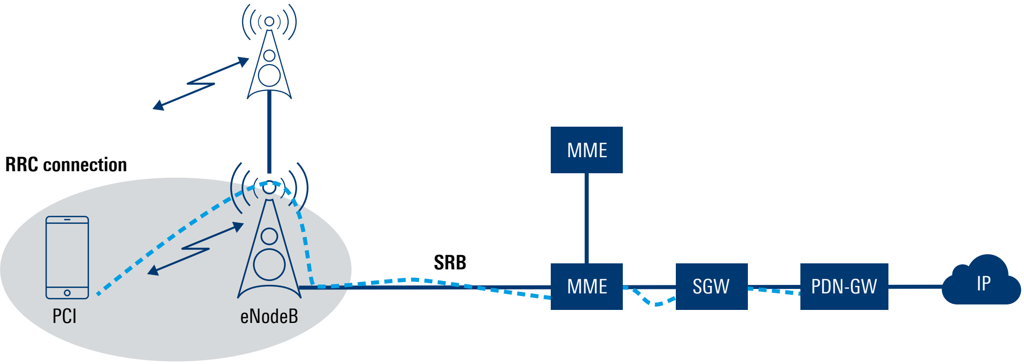
3.1 System components

The general LTE system architecture is shown in Fig. 4. It consists of the core network and the access network. LTE architecture is relatively flat compared to previous cellular technologies. Core network nodes include the mobility management entity (MME), serving gateway (SGW) and packet data network gateway (PGW). The radio access network (RAN) nodes include eNodeB.

3.1.1 Typical LTE operation

When user equipment (UE) is powered up, it becomes a radio resource control (RRC) connected with eNodeB. eNodeB forwards the registration request on behalf of the UE to the mobility management entity (MME). The MME is responsible for UE registration, session management, mobility management and security procedures. Once the MME registers the UE, it requests the PGW via the SGW to allocate an IP address to the UE. When the PGW allocates an IP address, the SGW communicates this information back to the UE via the MME and eNodeB path. The SGW and PGW are responsible for allocation of IP addresses and providing access to data traffic to the user. The base station in the radio access network (RAN) is responsible for providing both control and user traffic to the UE over the air interface. In 4G LTE, unlike other technologies, only eNodeB constitutes the RAN portion of the network as shown in Fig. 4.

Fig. 4: LTE system architecture



4 LTE RAN KPIs

4.1 Types of LTE RAN KPIs

The service experienced by end users is measured with a number of performance indicators that are aggregated into a KPI. In line with the 3GPP standard, there are six main KPIs that directly influence network performance and end-user experience:

- **Accessibility** defines how easy it is for users to obtain requested services within specified tolerances and other conditions. Session setup time and call success rate are examples of accessibility KPIs.
- **Retainability** defines the ability of the network to continuously provide requested services under given conditions for a specified period of time. One KPI here is the session abnormal release rate, which means poor retainability for a network.
- **Integrity** means the degree to which a service is provided without excessive impairments, for example uplink (UL)/downlink (DL) throughput, latency and packet loss.
- **Mobility** is when a user moves from one cell to another. Handover and other mobility related performance factors are measured with mobility KPIs.
- **Availability** is the percentage of time a cell is available. Although a cell may sometimes seem to be up and running, it can be dormant or out of service due to some anomaly or disabled manually for operator maintenance. Poor network availability or a complete outage can be the result.
- **Utilization** refers to the simultaneous usage of network resources without affecting the end-user experience.

These RAN KPIs and their immediate dependencies on various PIs and parameters are shown in the below table.

KPIs and their immediate dependencies

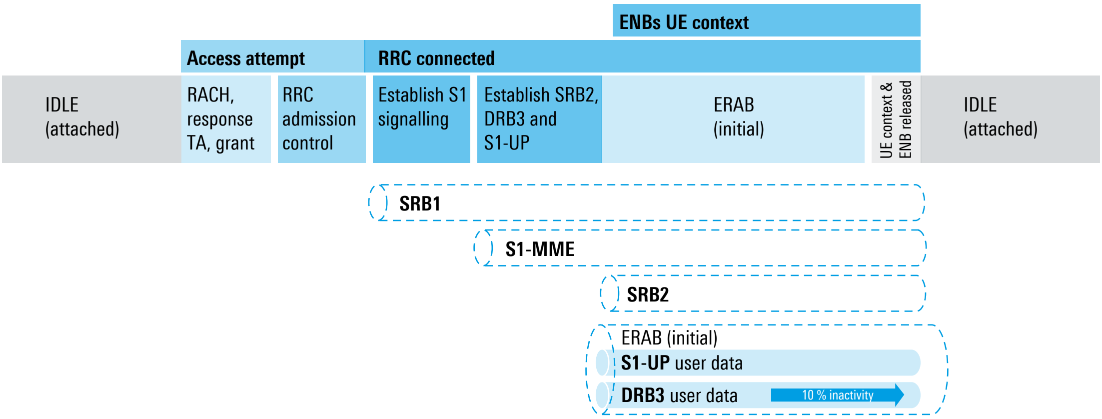
Accessibility	Retainability	Integrity	Mobility	Availability	Utilization
► RRC portion ► S1 portion ► E-RAB portion	► Abnormal UE context release ► Abnormal E context release	► DL/UL throughput ► Packet loss ► Latency	► Preparation failure rate ► Execution failure rate	► Partial cell ► Sleeping cell	► Licenses ► System load ► Processor load ► Physical resources

5 CASE STUDY: LTE ACCESSIBILITY

5.1 Anatomy of LTE accessibility

To explain the concept and dependency of KPIs, consider the RRC connection attach procedure in the previous table. The UE is already attached and has a default evolved packet system (EPS) bearer setup. The diagram shows the UE making a radio access request to either send a user data mobile originating (MO) call or respond to a page, i.e. MT.
The procedure and flow are similar for sending a tracking area update (TAU), except there would be no UE release due to inactivity because the MME would be responsible for removing the context.

Fig. 5: Anatomy of an RRC connection



The different steps for this radio access connection request mean:

- During the access attempt phase, there is a random access channel (RACH) attempt from the UE followed by a response from eNodeB, which provides the timing alignment and UL grant for the UE. In addition, counters for the RA attempt and RRC connection requests are pegged at the same timebase.
- As a result of the access attempt, eNodeB checks for resources to support the connection request. If resources are available, the connection request is accepted and connection success counters are triggered.
- Once the MO or MT request is accepted by eNodeB, it is sent to the MME on behalf of the UE. After the initial message to MME is received, the message response from the MME triggers the S1 signaling establishment success. Counters associated with the S1 signaling establishment are triggered at the same time.
- Finally, since the RRC has been reconfigured, the evolved radio access bearer (ERAB) initialization is established and the counters associated with the ERAB are pegged.
- The user plane is established and eNodeB has full context of the UE in view. Now user plane packets can be transmitted to and from the network and UE.

The pegged counters and various steps in the MT or MO accessibility process are illustrated in Fig. 6. Realize that even though accessibility affects end-user perceptions and is measured as a KPI from a business and technical perspective, has a number of PIs and various steps that are measured as sub-KPIs and field measurements. Measurement and adjustment of these performance metrics during the optimization process ultimately impacts the accessibility KPI.

5.2 Field performance metrics and KPIs

In section 4.1, we discussed how high-level KPIs are measured and tracked at the consumer and executive level. Now we will discuss major field performance metrics that are monitored and optimized to have an ultimate impact on end-user KPIs.

The key KPIs for network performance described in section 4.1 depend on a number of PIs. These sub-KPIs or PIs are monitored and measured continuously for an accurate KPI value. In field measurements, performance engineers always want to maintain these performance measurements. When these values are maintained, the rest of the network KPIs will perform well.

Major field KPIs and the category under which they fall are shown in the below table.

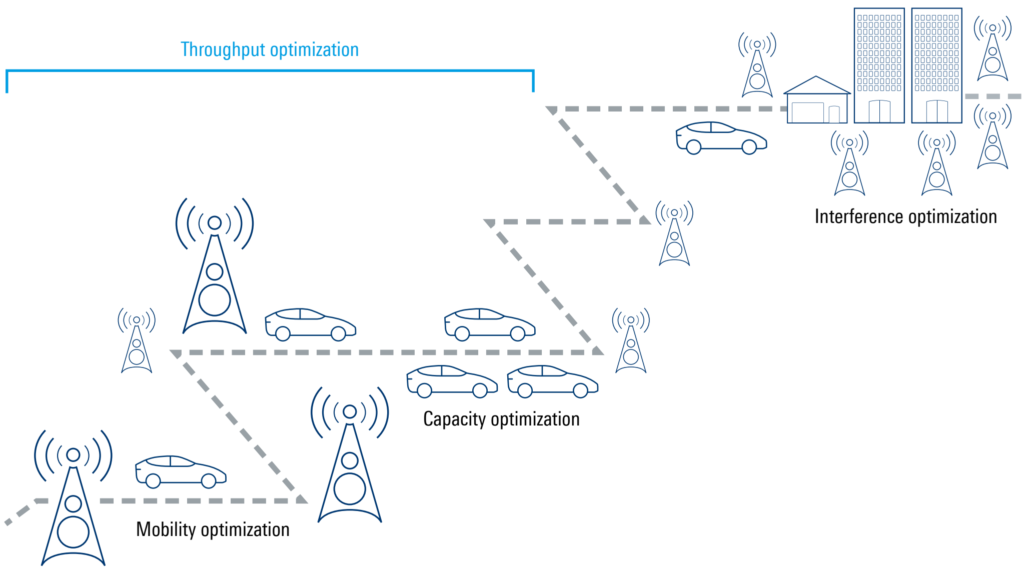
Key performance metrics and field measurements			
KPI name			**KPI category**
Application services	PS data services (FTP, HTTP, etc.)	service accessibility in %	accessibility
		completed session ration in %	accessibility
		single-user throughput in Mbps	utilization
LTE E2E network service	control plane	attach time in ms, $attachTime = t_{attach\ complete} - t_{attach\ request}$	integrity
		attach success rate in %	accessibility
		service request (EPS) time in ms	integrity
		service request (EPS) success rate in %	retainability
		handover procedure time in ms	mobility
		handover success rate in %	mobility
	user plane	RTT in ms	integrity
		single-user throughput in Mbps	utilization
		service interrupt time (HO) in ms	mobility
Radio bearer services	user plane	single-user throughput in Mbps	utilization
		cell throughput in Mbps	utilization

6 OPTIMIZATION WALKTHROUGH

6.1 Scenario

For a field measurement optimization walkthrough, consider the scenario of a user moving through different parts of a city – from a suburban to urban area. When and how different measurement and field optimization metrics are applied is shown in Fig. 6. The overall network optimization is applicable throughout the user journey, however specific scenarios are shown for ease of understanding.

Fig. 6: Optimization walkthrough scenario



6.2 Coverage optimization

Coverage optimization is the key for LTE network optimization. One of the highest costs in RAN optimization is coverage measurement and optimization. This usually requires intensive GPS based drive testing followed by offline or real-time analysis and correction. Drive tests and walk tests conducted a few times a year can be enhanced with crowdsourced data collected from real subscribers to create a more granular geographic distribution than would be possible with cell level stats.

Two of the thresholds for some of the coverage issues based on signal strength are:

- Coverage holes definition: RSRP < –120 dBm
- Weak coverage definition: RSRP < –105 dBm

The main method of coverage optimization includes adjustment of the antenna azimuth, down tilt, height and location of the site as well as adding new sites or RRU for the poor coverage area, adjustment of the RS power, etc.

6.2.1 Main parameters for UL and DL coverage

The main parameters that impact UL and DL coverage are shown in this table.

DL and UL coverage parameters	
DL coverage	**UL coverage**
qRxLevMin	A factor
RSpower	p0NominalPUSCH/p0NominalPUCCH
SCH power offset, PBCH power offset, PCFICH power offset, PHICH power offset, PDCCH power offset	initial UL_SINR target for PUSCH
pboffsetPDSCH, pboffsetPDSCH,	maximum UL_SINR target for PUSCH
Cell DL total power	minimum UL_SINR target for PUSCH

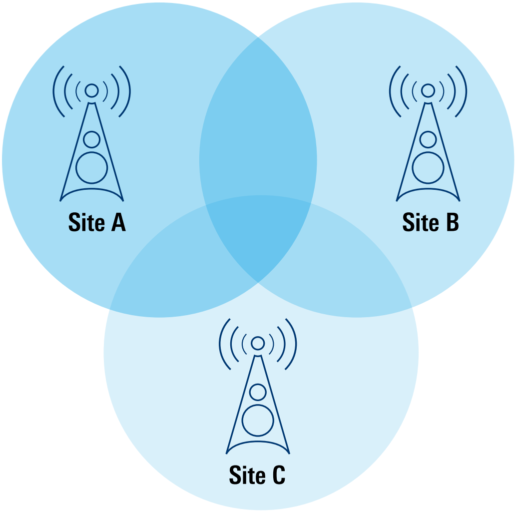
The impact of each parameter on DL and UL coverage is listed below:

- **qRxLevMin:** This parameter specifies the minimum required receiver level in a cell. A very low (more negative) value of qRxLevMin will enable more UE to be connected to the LTE network, but that will impact the access success rate and paging success rate. A high (less negative) value of qRxLevMin will result in a smaller amount of UE connected to LTE network.
- **UL PUSCH coverage:** Different kinds of UL signal interference and noise ratios (SINR) are chosen according to the service to ensure that the target SINR at the cell edge is not low enough to cause synchronization problems.
- **A factor:** This is intended to allow partial compensation of the path loss. The value of this parameter represents a tradeoff between minimizing interference and maximizing throughput. Its value must be set according to the client's desired network behavior.
- **p0NominalPUSCH:** This power control parameter represents the necessary signal level per radio bearer for correct decoding and is sent over the broadcast channel. This parameter impacts the UE power and network interference level before any power control commands are received from the eNodeB. Higher parameter settings will improve the PUSCH reception but will also drive up the UE TX power, leading to potential interference in neighboring cells.

6.2.2 Overlapping coverage

LTE networks use the same frequencies throughout the network and if the coverage overlap area is large, cells can cause a lot of interference with each other. The downside of interference is that it reduces throughput and degrades user QoE. Scanner reference signal received power (RSRP) measurements provide the most accurate method of identifying interfering sites and finding the source of strong interferers.

Fig. 7: Interference with neighboring sites



Pilot pollution is another cause of overlap coverage. Pilot pollution downsides include frequent cell reselection when idling, ping-pong handovers, low SNR and high block error rate (BLER), dropped calls and low throughput. Pilot pollution can be improved by changing the antenna tilt, azimuth and possibly the eNodeB power for interfering cells. Other methods include changing the antenna type and height or adding a new site/radio resource unit (RRU) to create dominance.

6.2.3 Extended coverage

Large cells are needed in coastal areas, sea environments, rural areas, etc. and LTE cells can cover up to 100 km, which determines the maximum timing advance value that can be sent to a UE. This value provides the UE with a minimum amount of processing time after receiving data during downloads and before transmitting a response in an upload.

For each cell, the maximum desired cell range defined by the 3GPP can be from 1 km to 100 km. The important thing is to carefully select the correct combination of physical random access channel (PRACH) format type and special subframe type. Either the PRACH format or special subframe type form the upper limit for the maximum cell radius, regardless of the link budget.

PRACH delay and SINR can limit cell size.

6.3 Capacity optimization

Capacity optimization focuses on improving resource utilization and maximizing traffic throughput. Not only for user plane capacity, but also capacity for control signaling solutions and user connectivity. User throughput is an important metric in capacity optimization.

When analyzing the root cause of capacity and investigating low LTE throughput, analyzing the radio conditions, signaling flows, logging messages and cell loading is important to understanding the reasons for low throughput.

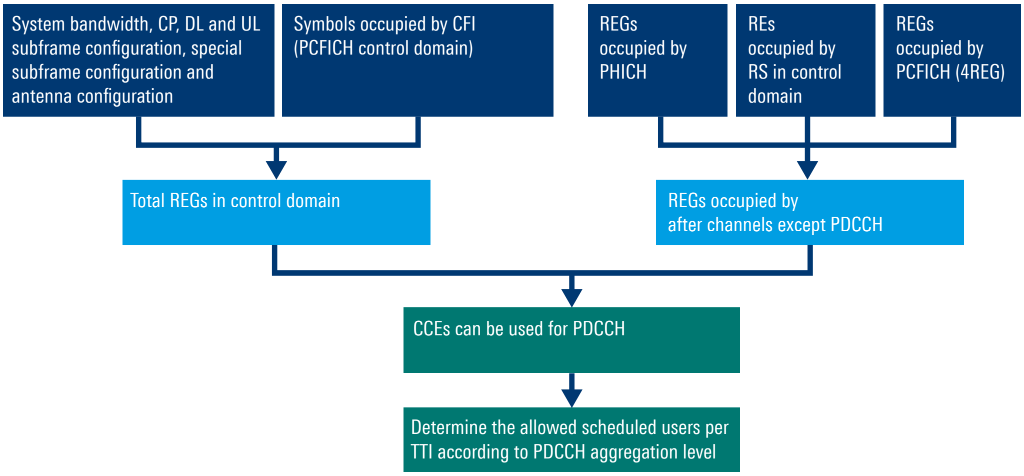
6.3.1 Physical downlink control channel (PDCCH) capacity

The PDCCH transfers DL control information for scheduling DL resources on physical downlink shared channel (PDSCH) and UL resources on the physical uplink shared channel (PUSCH). PDCCH is critically important since air interface scheduling and load depend upon PDCCH capacity.

PDCCH symbols at the beginning of each subframe can be dynamically adjusted based on the load and radio conditions. UE with poor radio coverage will require eight control channel elements (CCE) for each PDCCH transmission, whereas a UE with good radio coverage may only need one CCE. From a capacity perspective, higher aggregation levels should be employed at the cell edge and lower aggregation levels for users close to the cell. PDCCH capacity is measured in CCEs, which are nine sets of resource element groups (REG) or 36 resource elements (RE), since each REG contains four REs. PDCCH coding is restricted to quantum phase shift keying (QPSK) to allow users to decode the PDCCH channel even in low SINR conditions.

A simplified flow of the PDCCH capacity analysis procedure is shown in Fig. 8.

Fig. 8: PDCCH capacity analysis



6.3.2 Number of scheduled UEs

The number of users in a cell impact user throughput (capacity). If too many users access a cell and saturate the eNodeBs when additional UE accesses the cell, user throughput will be low.

The maximum number of active UE units depends on the RAN license. When the maximum number of users is restricted, the number of active users can be improved by increasing the inactivity timer (a system parameter that controls the transition from the RRC connected state to an idle state). The share of connected users depends on the RRC inactivity timer. The lower the value (inactivity timer, range from 10 s to 65 535 s, step 1 s, default 30 s), the more connected users and UE can switch from active to idle earlier. However, this affects the user experience. When new data service transmissions are made, UE will frequently establish a session. The eNodeB triggers an RRC connection release procedure when the inactivity timer expires.

Based on the user activity in connected mode, connected users are categorized in:

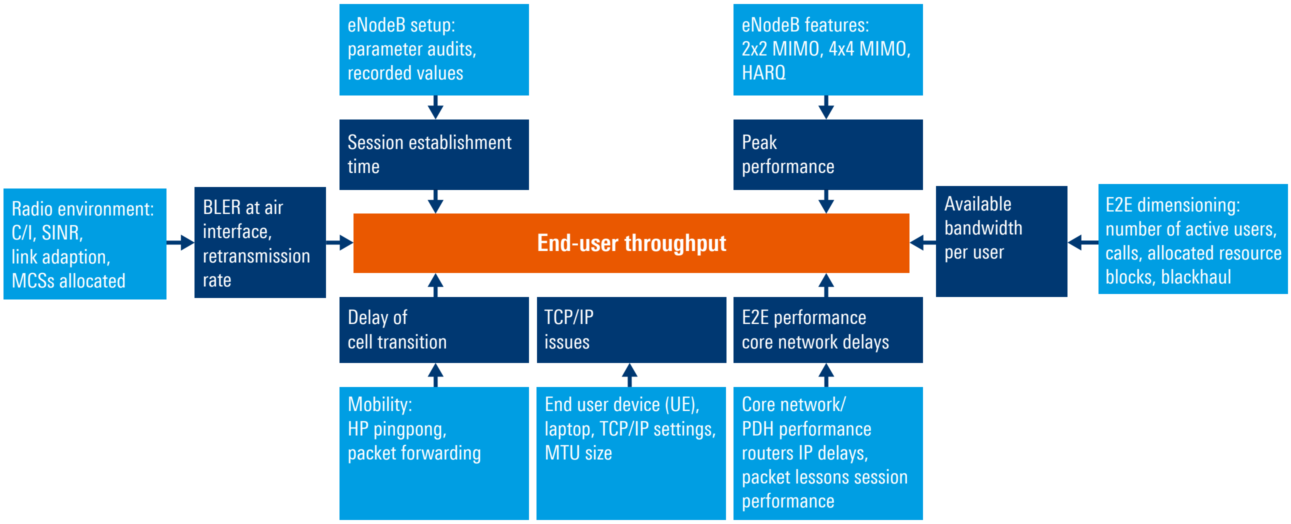
- **Actively scheduled user:** The number of actively scheduled users equals the UE units per transmission time interval (TTI) is scheduled by eNodeB; eNodeB capacity has a license feature. The number of actively scheduled UE unit for UL depends on the PRACH channel, SRS, and PUCCH; the number of actively scheduled UE units for DL depends on the hybrid automatic repeat request (HARQ), physical HARQ indicator channel (PHICH) and PDCCH.
- **Connected user:** Connected user is a 3GPP defined concept defined as RRC connected UE. A user is considered as connected if the UE has at least one established data radio bearer (DRB). When UE is in the RRC connected state, it does not necessarily need to transfer any data. The maximum number of simultaneously connected users depends on the digital unit hardware. The number of RRC connected users is relevant for radio network dimensioning. Usually a single cell can offer no less than 1200 connected users.
- **Attached user:** A connected user is different than a simultaneously attached user. Simultaneously attached users in the evolved packet core (EPC) include users in both the RRC idle and RRC connected states. Another critical distinction is that connected users (including detached users) are not the same as subscribers in the cell.

6.3.3 DL data rate optimization

In LTE, DL throughput directly correlates to SINR. Typically, UE has an algorithm to report the channel quality indicator (CQI) to the eNodeB based on the SINR measurement. DL UE throughput increases with CQI or PI usage and as DL BLER or UE eNodeB distances decrease.

The general troubleshooting strategy for improving end-user throughput is described in Fig. 9 along with different factors responsible for poor throughput.

Fig. 9: DL throughput dependency



One key insight is that end-user throughput is the aggregate of many factors, not just one. While troubleshooting throughput issues, the following indicators and counters need to be investigated:
- Excessively high BLER (bad coverage)
- DL interference (bad CQI)
- PIs parameters
- Scheduling algorithm
- Low demand
- CQI reporting frequency
- Other (VSWR, backhaul capacity)
- Analysis flow for DL throughput investigation if backhaul or other physical issues work well
- CQI and 64/16QAM ratio
- UE scheduling percentage of TTIs
- Physical resource blocks (PRB) and PDCCH utilization

6.3.4 UL data rate optimization

Similar to DL throughput, UL throughput optimization is important, since different features affect UL throughput. UL scheduler assignments depend on the number of PRBs allocated to each UE. The UL adaptive modulation and the coding schemes determine the MCS for UE every time it is granted UL resources, whereas the adaptive transmission bandwidth will reduce the number of PRBs assigned to the UE in the UL based on the UE power headroom. The general troubleshooting strategy and the different factors responsible for poor UL throughput are:
- High BLER (bad coverage)
- UL interference (high RSSI)
- Low power headroom
- Scheduling algorithm
- Low demand
- Other (VSWR, passive intermodulation (PIM), backhaul capacity)
- Alarm and parameter/feature check
- RSSI: high UL RSSI would impact the UL throughput
- Percentage of 16QAM samples
- PUCCH and PUSCH SINR
- Power limited UEs

6.4 Call drop optimization

Dropped calls cause an abnormal release, which leads to a poor user experience and ultimately to subscriber attrition, which affects cellular operators' business. The definition of abnormal session release can be explained by the release of the E-RAB, which has a negative impact on the end-user experience. Call drop is usually caused by an RLF. An RLF means the radio link between the eNodeB and the UE is lost. There are various radio connection supervision schemes in LTE to monitor the air interface link:
- UE detects DL sync by decoding PDCCH/PHICH and the BLER performance
- UE detects RLF by T310 expiry, maximum number of RLC retransmissions, integrity check failure, handover failure (T304 expiry) or non-handover related RA problem
- eNodeB detects RLF with PUSCH RLF, CQI RLF, Ack/Nack RLF, RLC failure SRB/DRB
- eNodeB initiated release: TA timer expiration and maximum RLC retransmissions exceeded

6.4.1 Reasons for call drop and optimization

Reasons for poor retainability include but are not limited to coverage issues, handover issues, neighbor issues, interference and other abnormal events. Some of the major call drop reasons are:

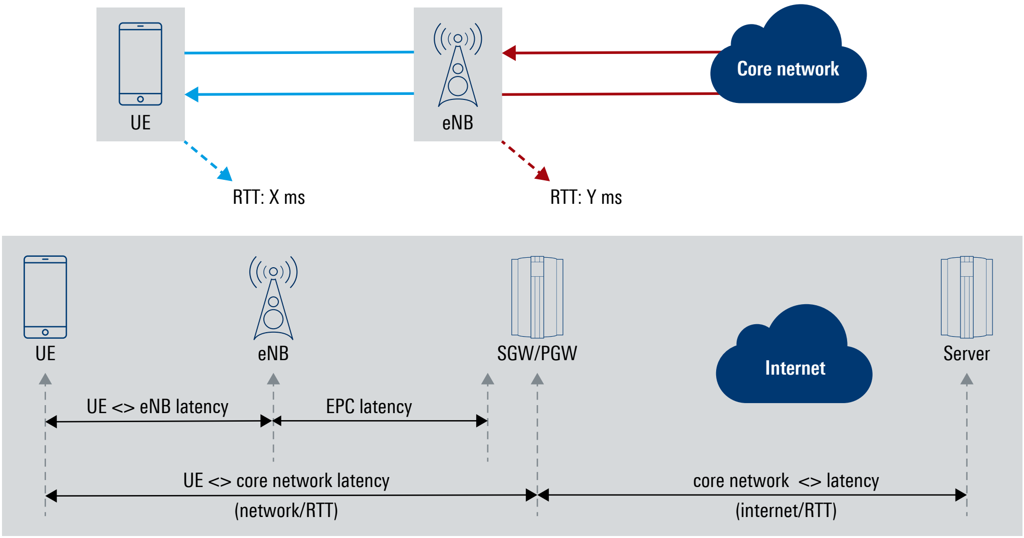
- Poor signal quality in the UL and DL due to poor coverage or path imbalance, faulty RRU
- RF issues, limited TX power
- As the UE's RSRP approaches –110 dBm or its SINR approaches –5 dB, the UE may not have sufficient signal strength to maintain the session, which can result in call drops
- Interference in DL and UL
- Handover failure in target eNodeB
- No handover command is sent or RA failure takes place at handover
- Handover timer expiry
- Admission reject due to lack of licenses
- Release due to EUTRAN generated reason
- RLC failure, DRB, RLC, failure SRB
- Load balancing TAU required
- RRC reconfiguration timeout, RRC reestablishment reject due to parameter misconfiguration
- S1 reset due to S1 link issues

The reasons for call drops listed above can easily be improved by tuning the timers T310 and T311 as well as out-of-sync (N310) and in sync (N311) and the recommended values for maximizing retainability performance. If the drop event is found, the entire procedure should be investigated to analyze poor retainability.

6.5 Latency optimization

Latency is the most important KPI for applications with a bursty traffic profile and an important KPI when looking at real-time services. Latency is divided into control plane latency and user plane latency as shown in Fig. 10. Control plane latency involves the network attachment operation while user plane latency only considers the latency of packets when the UE is in the connected state. Low user plane latency is essential for delivering interactive services such as gaming and real-time voice.

Fig. 10: Control plane and user plane



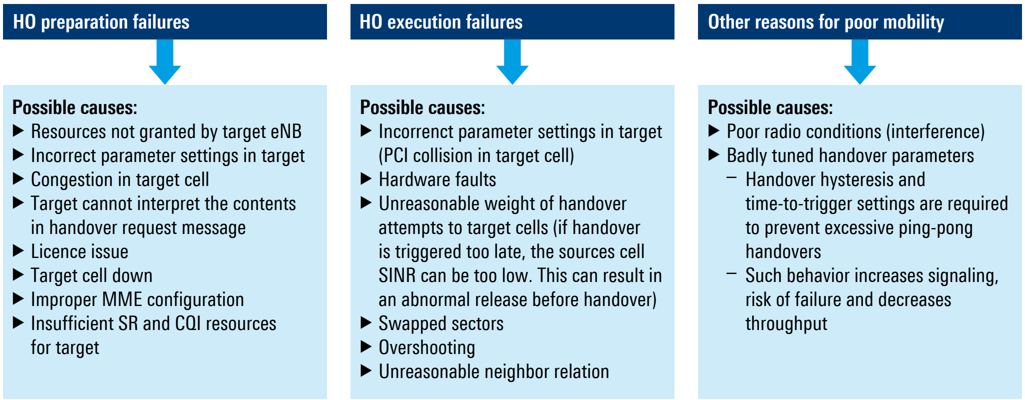
The different latency related KPIs that a performance engineer needs to track in order to improve the overall performance of latency KPI are shown in the below table.

Control plane and user plane latency KPIs			
Control panel		**User plane**	
KPI name	critical	KPI name	critical
First page response time	yes	Dedicated bearer activation time	no
UE activation time (idle to active)	yes	VoIP call end time (mobile-to-mobile/PSTN)	no
Service request setup time	yes	VoIP mobile-to-mobile mouth-to-ear delay	yes
MO VoIP call setup time (mobile <> PSTN)	yes	VoIP mobile-to-mobile packet latency	yes
Mobile-to-mobile VoIP call setup time	yes	VoIP mobile <> mouth-to-ear delay	no
Ping RTT between UE and application server (unscheduled and prescheduled)	no	VoIP mobile <> land over internet packet latency	no
Initial attach/detach time	no	VoIP mobile <> land over PSTN packet latency	no

Mobility optimization

Mobility is the key factor for ensuring that users can move freely within a network. The term mobility refers to both idle mode mobility and connected mode mobility. The idle mode tasks can be divided into public land mobile network (PLMN) selection, cell selection and reselection and location registration. In connected mode, mobility expresses itself as a handover. A handover consists of the handover preparation phase and execution phase. In order to ensure a handover always succeeds, the handover preparation phase and execution phase need to be successful. Common reasons that can result in handover failure either in preparation phase, execution phase or other reasons are shown in Fig. 11. All of these impact the overall mobility KPI.

Fig. 11: Handover failure causes and reasons



HO preparation failures

Possible causes:
- Resources not granted by target eNB
- Incorrect parameter settings in target
- Congestion in target cell
- Target cannot interpret the contents in handover request message
- Licence issue
- Target cell down
- Improper MME configuration
- Insufficient SR and CQI resources for target

HO execution failures

Possible causes:
- Incorrenct parameter settings in target (PCI collision in target cell)
- Hardware faults
- Unreasonable weight of handover attempts to target cells (if handover is triggered too late, the sources cell SINR can be too low. This can result in an abnormal release before handover)
- Swapped sectors
- Overshooting
- Unreasonable neighbor relation

Other reasons for poor mobility

Possible causes:
- Poor radio conditions (interference)
- Badly tuned handover parameters
  - Handover hysteresis and time-to-trigger settings are required to prevent excessive ping-pong handovers
  - Such behavior increases signaling, risk of failure and decreases throughput

6.5.1 Intra-LTE mobility optimization

Intra-LTE handover manages UE in connected mode and enables seamless mobility from one LTE cell to another. In contrast to idle mode, connected mode mobility is managed entirely by the LTE RAN based on measurement reports configured by and received from the UE. Only the hard handover is supported in LTE. Good handover performance ensures a good user experience. Modifying handover parameters help avoid or reduce handovers that are too early or too late and ping-pong handovers, which impact overall system performance. In a live network, each of the events (A3, A4 or A5) can be used in the LTE system with the intra- and interfrequency handover decision. The major parameters for

LTE mobility events that affect the mobility optimization and handover performance in LTE are described below.

Handover parameters and their optimum values

Parameter	Description	Range	Defaults
a3Offset	offset value for event A3	– 30 to +30 (0.5 dB per step)	6 (3 dB)
hysteresisA3	parameter for entering/leaving measurement report triggering condition		1 dB
a3TimetoTrigger a5TimetoTrigger	the period of time necessary for the UE to trigger a measurement report for an event A3(A5); greatly depends on the speed of the UE and the coverage scenarios	0 ms(0), 40 ms(1), 64 ms(2), 80 ms(3), 100 ms(4), 128 ms(5), 160 ms(6), 256 ms(7), 320 ms(8), 480 ms(9), 512 ms(10), ..., 5120 ms(15)	320 ms
a3ReportAmount a5ReportAmount	number of reports when periodic reporting is used; 0 means that reports are sent as long as the event is fulfilled	1r(0), 2r(1), 4r(2), 8r(3), 16r(4), 32r(5), 64r(6), infinity(7)	infinity(7)
a3ReportInterval a5ReportInterval	the interval for event-triggered periodic reporting	120 ms(0), 240 ms(1), 480 ms(2), 640 ms(3), 1024 ms(4), 2048 ms(5), 5120 ms(6), ..., 60 min(12)	240 ms
cellIndividual OffsetEUran	offset value specific to the neighbor cell relationship; this parameter can be applied individually to each neighbor cell for load management purposes	low value will delay the HO; the higher the value allocated to a neighbor cell, the "more attractive" it will be	-
a5Threshold1	RSRP threshold1 used for triggering the EUTRA measurement report for event A5	0 to 97 (1 dB per step), –140 dBm to –44 dBm	-
a5Threshold2	RSRP threshold2 used for triggering the EUTRA measurement report for event A5	0 to 97 (1 dB per step), –140 dBm to –44 dBm	-

7 SUMMARY

This white paper explains the specific field level PIs and KPIs that impact the performance and optimization of an LTE network. It was emphasized that in order to have good E2E performance, each and every PI and KPI needs to be optimized. While a single KPI can affect the user experience in a specific context, true performance management is achieved by making sure that each and every parameter of the network is tuned accordingly.

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10 ABBREVIATIONS

3GPP	third generation partnership project
BLER	block error rate
CCEs	control channel elements
CQI	channel quality indicator
EPC	evolved packet core
EPS	evolved packet system
ERAB	evolved radio access bearer
DL	downlink
HO	handover
KPIs	key performance indicators
LTE	long term evolution
MCS	modulation and coding scheme
MIMO	multiple input multiple output
MME	mobility management entity
MNO	mobile network operator
MO	mobile originated
MOS	mean opinion score
MT	mobile terminating
OPEX	operating expense
OTT	over-the-top
PDCCH	physical downlink control channel
PGW	packet data network gateway
PHICH	physical HARQ indicator channel
PIs	performance indicators
PIM	passive intermodulation
PRACH	physical random access channel
PRB	physical resource blocks
PSTN	public switched telephone network
PUCCH	physical uplink control channel
PUSCH	physical uplink shared channel
QoE	quality of experience
QoS	quality of service
RA	random access
RAN	radio access network
REs	resource elements
REGs	resource element groups
RLC	radio link control
RLF	radio link failure
RRC	radio resource control
RRU	remote radio unit
RSRP	reference signal received power
RSSI	received signal strength indicator
RTT	roundtrip time
SINR	signal interference to noise ratio
SGW	serving gateway
SNR	signal to noise ratio
SRS	sounding reference signal
TA	timing advance
TAU	tracking area update
TTI	transmission time interval
UE	user equipment
UL	uplink
VSWR	voltage standing wave ratio

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