A major challenge for operators is the effect of rising consumer expectations when it comes to performance of the services they use, in particular over-the-top (OTT) services such as video sharing and social networking using smartphones. Data traffic is being driven by mobile-broadband and smartphone usage, and user behavior and demands are changing quickly. Complex and constantly evolving multi-vendor networks and services are placing considerable demands on service management, and as a result, operators must determine how to become more competitive in terms of the service-quality experience for the user.

As operators strive for the optimal transformation of network resources and services into commercial offers – and ultimately revenue – their attention is shifting from managing the performance of technical equipment to managing the delivery of high-quality services. To be successful, operators will need systems that support service-centric and user-centric management.

**Achieving the desired user experience**

Fundamental to the concept of service-centric management is set of interconnected components that allow operators to monitor, control and troubleshoot product-generic and implementation-independent service elements.

A first step towards achieving the desired user experience is to understand how users perceive the quality of the service being provided. One way to achieve this is to first evaluate the way users experience, for example, the videos they watch on websites such as YouTube or games they play on social-networking sites, and what their tolerance levels are for service quality. This understanding should then be transformed into measurable service-quality indicators and targets by applying the user-experienced service performance (USP) concept.

When measured accurately, service quality is usually representative of its share of the user-perceived quality of experience (QoE). As illustrated in Figure 1, the use component is only one element of the complete QoE aspect. Network operators need to be able to view and interact with the network using each one of the service-quality indicators to make the business decisions that will enable them to deliver the desired level of service quality – and ensure user satisfaction.

A second step to achieving the desired user experience is to assess network functions such as QoS mechanisms, radio scheduling and load regulation. It is vital to take a service-centric approach to each of these functions so that limited network resources are used in a suitably balanced way.

Finally, some resource-performance-analysis features are needed. Such features can provide a breakdown of the root cause of a service-quality breach, together with suggested actions to resolve incidents, prevent future occurrences and support cost-effective proposals for network expansion.

Together these three elements – insight into user perception; control of

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**BOX A Terms and abbreviations**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>API</td>
<td>application programming interface</td>
</tr>
<tr>
<td>a.r.i.</td>
<td>accessibility, retainability, integrity</td>
</tr>
<tr>
<td>CN</td>
<td>control network</td>
</tr>
<tr>
<td>Core IP</td>
<td>Core Internet Protocol</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>HTTP</td>
<td>Hypertext Transfer Protocol</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>ITU-T SG12</td>
<td>International Telecommunication Union Telecommunication Standardization Sector Study Group 12</td>
</tr>
<tr>
<td>NE</td>
<td>network element</td>
</tr>
<tr>
<td>OTT</td>
<td>over-the-top</td>
</tr>
<tr>
<td>P.NAMS</td>
<td>non-intrusive parametric model for assessment of performance of multimedia streaming</td>
</tr>
<tr>
<td>QoE</td>
<td>quality of experience</td>
</tr>
<tr>
<td>QoS</td>
<td>quality of service</td>
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<tr>
<td>QoSS</td>
<td>quality of system service</td>
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<tr>
<td>RAN</td>
<td>radio-access network</td>
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<tr>
<td>RCA</td>
<td>root-cause analysis</td>
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<tr>
<td>R-KPI</td>
<td>resource key performance indicator</td>
</tr>
<tr>
<td>RTMP</td>
<td>Real Time Messaging Protocol</td>
</tr>
<tr>
<td>RTSP</td>
<td>Real Time Streaming Protocol</td>
</tr>
<tr>
<td>S-KPI</td>
<td>system service key performance indicator</td>
</tr>
<tr>
<td>SOC</td>
<td>Service Operation Center</td>
</tr>
<tr>
<td>SON</td>
<td>self-organizing network</td>
</tr>
<tr>
<td>SQI</td>
<td>service quality incident</td>
</tr>
<tr>
<td>U-bearer</td>
<td>Universal Mobile Telecommunications System-bearer</td>
</tr>
<tr>
<td>UE</td>
<td>user equipment</td>
</tr>
<tr>
<td>UI</td>
<td>user interface</td>
</tr>
<tr>
<td>URL</td>
<td>uniform resource locator</td>
</tr>
<tr>
<td>USP</td>
<td>user-experienced service performance</td>
</tr>
<tr>
<td>VoD</td>
<td>video on demand</td>
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</table>
resource usage; and root-cause analysis – make it possible to provide service delivery at the targeted service-quality level. The way in which these elements are combined in a service-centric management system is shown in Figure 2.

Network operators can effectively control service quality by using a service-centric management system, which allows them to:

- set a desired level of service quality for each service;
- set priorities for services and user groups;
- monitor service quality;
- respond to incidents related to service quality; and
- obtain information about cost-effective network expansions.

The priorities for services and user groups are based on targets for desired service quality and cross-service priorities. These targets and priorities are used in combination with network-related parameters – such as spectral efficiency – to allocate network resources. Service-quality targets are used as input parameters for self-organizing network (SON) functions and other algorithms in the network. When quality levels are breached, a root-cause analysis (RCA) process is triggered to discover the source of the incident, and targets are used as input for automatic and manual optimization of the entire network under the control of the operator.

The relationships between service quality as perceived by users, preset service-quality target values, analysis of service-quality breaches, and automatic optimization are key to making effective business decisions about service propositions, acting on or forecasting service performance, and planning network expansion to support mobile-broadband-traffic growth. Independent and generic service entities, known as system services, improve ease of use and create synergies to manage the growing amount of services and implementations.

**Measuring quality of system services**

Ericsson’s USP concept introduces a service model that includes system services, as well as a quality model which is described in more detail in 1, 2, 3, 4. As illustrated in Figure 3, system services are used and experienced by users, and...
How to measure someone’s feelings

- include

QoS.

- performance indicators (S-KPIs) define the way of expressing user-perceived quality of a service.

- web-browsing system service. To monitor the performance of applications such as web browsing and video-on-demand for YouTube clearly need to be monitored to ensure efficient resource management.

- The smartphone application for Facebook, which is a resource service as opposed to a system service, is another potential root cause of service breaches, and as such needs to be monitored. To use this application, users first need to download it – a file-transfer system service is needed to perform this action. Accessing Facebook through the application, or directly with the URL, uses a web-browsing system service to monitor the performance of applications such as Facebook for smartphones requires assessment of several system services as OTT primitives, such as gaming, messaging, file transfer, and web browsing.

- Quality of system service (QoS) is a way of expressing user-perceived quality as a single value. System-service key performance indicators (S-KPIs) define the relevant elements for assessing QoS.

- As shown in Figure 4, these S-KPIs include:

- accessibility – the probability that a user can access a service;
- retainability – the probability that a user can keep the service once accessed; and
- integrity – the service quality experienced during use of the service.

The USP concept – including a list of defined system services and S-KPIs – forms the fundamental structure of a future-proof service-centric quality management system. User studies should be utilized to select appropriate S-KPIs for USP, understand user perceptions and determine service thresholds.

- Accuracy

Measuring service quality in a way that accurately captures how users perceive it requires a holistic approach. System services can be analyzed to reflect local usage, taking into account service-quality expectations and tolerance levels of local users. As such, the target value of an S-KPI can differ significantly among operators and networks as well as over time.

- User-perceived quality depends on many factors, some of which can be controlled directly by the operator – such as RAN and Core IP packet throughput, packet loss and delay. Others, such as source content, server type and terminal type, cannot be directly controlled. New methods, some of which are being standardized, are now available for measuring user-perceived service quality for video and voice.

- The accuracy of an S-KPI depends on several parameters, including where the measurement is made, the availability of measurement data and the model used for calculating it. Measurements made close to, or in, the terminal are generally more accurate than measurements made inside the network – away from the user.

- To ensure accurate results, S-KPIs should be calculated with a sufficient amount of data. The use of aggregated measurement data – such as that retrieved with counters – provides less accurate results than the use of specific network-event data.

- When quality models are used to assess user-perceived service quality, the accuracy of the assessment depends on the type of model used. An algorithm to determine the perceived quality of audiovisual services – P.NAMS – is currently being standardized in the ITU-T SG12 [4]. As its computational complexity is low and prediction performance reasonably good, this algorithm can be used for network-based quality monitoring of audiovisual services.

- Data from several sources, including terminals, is used to calculate S-KPIs. Being able to analyze the network in its actual state, with current traffic mix, parameter settings and new capabilities is essential. Using the right portfolio – including service-quality and the monitoring thereof, network control, and root-cause analysis – is important to ensure that new data sources can be included easily to support service-quality management.

- Measuring service quality in practice

The way in which operators choose their target levels for service quality depends on their business strategy. Service quality can be measured in the terminal or inside the network – on the control and user planes. Terminal measurements can potentially provide the best correlation to user-perceived quality, while network-based measurements are easier for an operator to deploy.

- Currently, only a limited number of standard application programming interfaces (APIs) in terminals – including smartphones – can be used for S-KPI measurements. This makes it difficult to implement an application to measure and survey the performance of other applications. Solutions are being developed, but they do not yet meet all the requirements for measuring and managing service quality.

- To measure the performance of system services in a network, network nodes...
need to be service-aware or probes need to be deployed. Service-aware nodes cannot access information on the internal state of applications in the terminal. To some extent, however, this information can be obtained from the network interfaces carrying application data by monitoring protocols such as HTTP, RTMP, RTSP and FTP.

In practice, accurate service-quality measurement requires network-based measurements combined with service-aware features. Terminal-based measurements are a complementary data source and provide much more accurate estimates than network-based measurements as well as taking into account subscriber privacy.

**Controlling the use of network resources**

Traditionally, network performance is controlled and optimized by setting configuration parameters on individual network nodes. In service-centric management, the focus shifts from controlling network performance to controlling service quality, and service-level parameters should instead be set in the management system.

A service-quality target for each service is set according to the operator’s business strategy. By monitoring service quality, an operator can take a proactive approach to ensuring that targets are met, and can continue to maintain a favorable cost-performance balance.

The correlation between low-level network node parameters and service quality is complex, so low-level parameters are controlled by SON functions, some of which use service-quality-related parameters as input.

Network resources are finite, and when load is high, traffic needs to be prioritized. Priorities are set based on service type, subscription type and network efficiency. For example, a premium subscriber using a video service who has high service-quality targets will be assigned with a high priority. However, the scheduling of resources will also be determined with the radio conditions taken into consideration, weighing these against the service-quality targets so that they are balanced with appropriate use of resources – in this case, the radio spectrum.

The automatic optimization process is supplied with additional information created by a service-quality and network performance analysis. By considering all relevant input, this process ensures that SON optimization functions do not cause suboptimal use of network resources. For example, if a YouTube service-quality level is breached due to a bottleneck in the transport network, there is nothing to be gained by increasing the priority of the service in the radio network.

**Network performance analysis**

The strategy and goals of an enterprise determine the levels of service quality that it delivers, and support fulfillment of business objectives. The management function that analyzes service-quality and network-performance parameters helps the operator to optimize and expand their network and ultimately provide the desired service quality for users.

Ideally, this level of quality should be provided using SON features and prioritization algorithms. It is however important to consider that network resources are by nature limited making it almost impossible to provide data transport to every single user in the network with adequate throughput, and sufficiently low delay and jitter.

Incorrect or sub-optimized network and terminal configurations are common causes of breached service-quality targets. When these targets are not met, the RCA feature is triggered, either manually by the operator or automatically by the network.

Effective service-quality analysis correlates measurements and targets with network configuration and measurement parameters. This makes it possible to identify the reasons for service-quality degradation. The correlation function works at the user session level, connecting all measurement results to one session – such as a YouTube streaming session. The function identifies the main reasons for service-quality degradation, which can then be used to reconfigure or expand the network effectively.

Operators can view the results of an analysis on a map where problem areas are highlighted and, where available, combined with recommended solutions. These results can contain a variety of data related to terminal type, transport network bottlenecks, radio-network coverage issues, and capacity problems.

Examples of solutions that can be proposed by the analysis include: triggering an automatic tuning function, manually optimizing the network, or implementing a cost-effective network expansion. The output of the analysis can be used as input for automatic priority and SON algorithms.

**Root-cause analysis**

In a service-centric management system, faults and limitations in the network are detected as reduced levels...
How to measure someone’s feelings

When a service-quality target is breached, a service-quality incident (SQI) report is created, initiating a search for the source of the problem. The RCA process identifies the cause of the quality degradation and supports the restoration of desired service-quality levels.

The priority assigned to the SQI by the enterprise depends on the impact of the degradation on long- and short-term profitability. Some of the parameters used to calculate SQI priority are loss of income, damage to brand reputation, loss of service-fee income, subscriber compensation, and churn probability.

Once an SQI is created and its priority determined, it is queued with other SQIs until a solution can be reached. A business-driven Service Operation Center (SOC) ensures that SQIs are handled in order of priority.

An effective management system dynamically reassesses all ongoing SQIs to ensure that the highest-priority SQIs are always resolved first. The process from problem identification to resolution is as follows:

1. Detect an SQI or incident that will cause a quality-target breach;
2. Determine incident priority;
3. Inform user and enterprise about new incidents;
4. Execute RCA;
5. Determine solution;
6. Deploy solution;
7. Inform users and enterprise about resolved incidents;
8. Compensate users; and
9. Conduct post-event analysis to identify possible process or product improvements.

In an effective management system, all or most of these steps are automated. This process is executed when SON functions are unable to prevent the network from delivering sub-target service quality. The cause of systems-service quality degradation can be found in the resources that deliver the service. The dependency relationship that exists between the S-KPIs and resource KPIs (R-KPIs) is used for RCA. These R-KPIs comprise a generic set of attributes that represent the quality of each connectivity resource.

Basing a resource service-model on connectivity rather than functionality is advantageous because resources are the traffic building blocks in the network. Suitable models represent the dependency structure of the connectivity resources that are included and the applicable R-KPIs.

Figure 5 shows an example of a resource-dependency model. It consists of logical connectivity objects such as high-level bearers and, in the lower part of the figure, connectivity entities from the physical layer down to the network equipment (NE). A service RCA system needs to be vendor-independent, and the analysis model should support new NEs without being redefined.

The output of the RCA refers to one or several managed objects, identifying the offending resource service along with a statement indicating which performance element caused the service-quality breach.

Conclusions

Consumer expectations for mobile broadband service quality are growing in parallel with traffic complexity and increased usage. To meet this challenge, especially when it comes to third-party OTT services, operators are making the transition toward service-quality management.

This transition requires the use of a new concept for managing service quality, where the focus is no longer on managing individual network nodes but on comprehensively managing service quality. The three essential cornerstones of this concept are the ability to:

1. Measure service quality as perceived by users;
2. Control network resources according to business-driven user- and service-type differentiated targets; and
3. Analyze service quality and network performance and identify the causes of quality incidents using RCA.

A complete service-centric management solution addresses many of the challenges now faced by operators—from understanding user perceptions to managing technical issues. Roadmaps for this solution should be developed with consideration for fluctuations in user expectations; cost-efficient and future-proof selection of service entities; the ability to deliver more accurate
and reliable measurements; and the opportunity to handle service breaches with SONs and other automatic features. Network operators will thus be able to better understand, plan for and satisfy user needs as a basis for price/performance differentiation of mobile broadband services. The use of S-KPIs that are independent of vendor, device, service or app reduces complexity, which saves time and provides greater user satisfaction at a lower cost.

**BOX B**

**Ease of use**

A key concern for users of service-centric management systems is ease of use, and the following elements must be addressed:

- **usefulness** – the system should be fit for the purpose;
- **ease of learning** – the system should be intuitive and should require relatively little training;
- **efficiency** – the system should be straightforward to use; and
- **desirability** – the system should be attractive to users and offer them added value.

These objectives for user experience can be achieved through the following characteristics, which can be applied to a management system:

- **coherent look and feel** – the UI should be consistent, regardless of underlying technology;
- **flexibility and personalization** – the UI should be tailored to the specific user;
- **integrated help and training** – the UI should support users, users should feel motivated to use it, and assistance should be easily accessible; and
- **simplicity and automation** – dull and repetitive tasks should be automated.

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