Radio access and transport network interaction – a concept for improving QoE and resource utilization

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Better customer experience

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In today’s networks, radio access and transport are largely unaware of each other, but are inherently related, as impaired conditions in either domain can adversely affect user experience. As QoE has a significant impact on customer satisfaction and customer retention

To improve overall QoE, a holistic approach to network architecture is vital – one that takes into consideration conditions in both radio and transport domains, and that results in the creation of proactive measures for preventing congestion.

The concept of RAN transport interaction (RTI) introduces coordination between the radio and transport domains, and aims to provide just the holistic approach needed to improve QoE. In this article, the principles and benefits of this concept are described, as is the high-level set of building blocks for the RTI solution, and the whole is exemplified with a few selected use cases. In some way, RTI can be viewed as an example of cross-domain interaction. Specifically, this article addresses the radio access and transport components of the overall network.

Why the call for new technology?
The increasing global dependence on mobile-networking services is causing congestion in networks. The rate of uptake of mobile broadband, for example, is set to rise significantly: in 2014, total global subscriptions topped 7 billion, which are set to rise to 9.2 billion by 2020. And so, congestion issues will continue to be among the more significant factors that impact user satisfaction.

While rapid developments in technology and community foundations, such as exploitation of new frequencies and concepts for energy conservation, are shaping next generation networks, perhaps the most significant change factor today is how society and individuals are using mobile-broadband services. The current demand for such services and capacity is on an upward curve that shows no signs of leveling off.

As networking services like mobile broadband rely on the entire network – including radio access, the transport network, data centers and the global internet – to ensure excellent QoE, applying a holistic approach to network architecture is crucial. As more information becomes available, related to say location, magnitude, origin, and duration of traffic, the easier it becomes to mitigate QoE impairment. However, as radio and transport domains do not share much information, they are largely unaware of each other.

Consequently, an impairment in one domain may go unnoticed by the other, making it difficult – or even impossible – to optimize resource usage and take the necessary actions to avoid the congestion.

The term impairment is used to indicate any source of QoE degradation related to, for example, traffic congestion, which results in packet delay, delay variations or dropped packets. Typically, sources of degradation tend to be interdependent and are often an indication that network resources are overutilized.

For example, traffic congestion may occur in the transport network at certain times and locations, and for given types of traffic. The radio access and/or the transport domain could try to mitigate such congestion but the lack of information sharing between them makes this task complex, and in some cases impossible to solve.

Not a one-to-one relationship

The transport network carries traffic to and from different types of radio domain and user. Typically, the transport network maps this traffic to the relatively small number of QoS classes used by transport network operators.

As a result, the transport network lacks the necessary granularity to differentiate traffic, leading to suboptimal

**Box A - Terms and abbreviations**

<table>
<thead>
<tr>
<th>BE</th>
<th>DPI</th>
<th>ECMP</th>
<th>GTP</th>
<th>H-QoS</th>
<th>LAG</th>
<th>MME</th>
<th>MPLS</th>
<th>PCRF</th>
<th>QoE</th>
<th>RAN</th>
<th>RAT</th>
<th>RNC</th>
<th>RTI</th>
<th>SDNC</th>
<th>S/PGW</th>
<th>TEID</th>
<th>UE</th>
</tr>
</thead>
<tbody>
<tr>
<td>best effort</td>
<td>deep packet inspection</td>
<td>equal cost multipath</td>
<td>GPRS Tunneling Protocol</td>
<td>hierarchical QoS</td>
<td>link aggregation group</td>
<td>Mobility Management Entity</td>
<td>multi-protocol label switching</td>
<td>policy and charging rules function</td>
<td>quality of experience</td>
<td>radio-access network</td>
<td>radio-access technology</td>
<td>radio network controller</td>
<td>RAN transport interaction</td>
<td>software-defined networking controller</td>
<td>PDN gateway</td>
<td>tunnel endpoint identifier</td>
<td>user equipment</td>
</tr>
</tbody>
</table>
network utilization, which has an impact on QoE.

**Encryption complications**
To improve its understanding of the traffic situation, the transport domain can use deep packet inspection (DPI) to get more information about granular flows at router ingress ports. For example, the tunnel endpoint identifier (TEID) included in the GPRS Tunneling Protocol (GTP) can be used to encapsulate various QoS bearers. However, for this to be useful, the transport network domain needs to know what type of traffic is addressed by the specific TEID. Unfortunately, when encryption like IPsec is applied – an approach that is widely deployed in LTE networks – the TEID cannot be read using DPI.

**Inadequate measurements**
Another possible way to improve the overall understanding of traffic is for the radio domain to access the transport domain's performance characteristics. This can be achieved through passive or active metrics, which can be accessed through, for example, application of the two-way active measurement protocol (TWAMP). However, metric-based methods may be too slow to react to traffic impairments that are highly time dependent. In addition, while measurement-based approaches are useful for providing end-to-end characteristics, they fall short of providing the information needed to pinpoint congestion.

The measurement approach is consequently inadequate for proactive network optimization, and is further inhibited by the fact that the radio domain is agnostic of the transport domain's capability to self-optimize – and so attempts to solve a congestion issue (based on observed conditions) may be futile if the problem has already been addressed by transport.

**Connecting radio and transport**
Given the limitations of existing technology, devising explicit interaction between the two – radio and transport – domains is a more appropriate method that offers significant advantages.

A number of models can be used to create the connection between radio and transport, such as a peer-to-peer or client-server model (with or without hierarchies). The solution described in this article uses an information-sharing model that boasts one significant feature: each domain controls the information that it shares with the other, and dictates exactly where that information may be used. Significantly, the decision to share or request information never results in a feedback loop, as explicit information sharing reduces or removes the occurrences of failure to mitigate against certain impairment conditions. The RTI problem and opportunity formulation is summarized in Figure 1.

**The described approach**
Solving congestion, as illustrated in Figure 2, is a two-step process, which first aims to proactively avoid congestion scenarios, and then to handle any unavoidable congestion.

Proactively minimizing congestion can be achieved by optimizing the use of available resources in both the transport and radio-access domains. Optimization in turn uses two methods: redistribution and rerouting. In the case of redistribution, the radio domain moves traffic around (when possible), effectively load-balancing in an optimal way across the backhaul transport network. In the case of rerouting, the transport network uses a number of techniques, like SDN-based traffic engineering, to make better use of available alternate paths.

Mechanisms can be applied to relieve relative starvation among the various radio-access technologies (RATs). For example, by applying a fairness mechanism, the transport network can use information received from the radio network to prevent starvation between different radio accesses during congestion conditions.

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**FIGURE 1** RTI problem (left) and opportunity (right) formulations

<table>
<thead>
<tr>
<th>Transport-unaware radio</th>
<th>RAN-unaware transport</th>
<th>Transport-aware RAN</th>
<th>RAN-aware transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAN</td>
<td>Transport</td>
<td>Transport path load and capacity</td>
<td>Granular RAN traffic treatment</td>
</tr>
<tr>
<td>Am I aware of congestion in the transport path? =&gt; QoE impact</td>
<td>Am I aware of granular RAN flows? =&gt; non-optimized transport paths</td>
<td>Optimal distribution of RAN flows to help avoid congestion in transport</td>
<td>Better utilization of available diverse paths</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reduction in network state and energy waste</td>
</tr>
</tbody>
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handover decision-making process. The best solution for cases where sizeable QoE degradations occur is to either mitigate or circumvent congestion. This first example use case – proactive congestion avoidance – addresses how information provided by transport helps the radio-access domain to make handover decisions that are more holistic in nature. To maintain connectivity between the RAN and a UE, traditional handover decisions are made on the basis of radio signal quality, which is assessed continuously. Handover to another cell is triggered when radio conditions become more advantageous in a neighboring cell. However, the level of transport congestion in each cell is not part of the handover decision-making process. To increase availability, and to be able to propagate traffic over multiple paths, mobile transport includes a degree of redundancy in the metro aggregation network – typically in terms of different ring or necklace topologies that use protection schemas and link aggregation groups (LAGs). However, closer to the radio access, transport networks tend to be built in a non-redundant tree shape and do not offer path diversity. Congestion often occurs in the access aggregation part of the network (see Figure 3), but may also arise in the metro portion, where mobile traffic merges with fixed residential and business traffic. Hop-by-hop path characteristic measurements performed in the transport network can be shared, providing the radio access with knowledge about transport congestion. This congestion information can be used to enhance the handover procedure. To avoid handover to a neighboring cell where the radio access is connected to a congested transport path, information about transport topology is needed. This information enables handover to neighboring cells that are connected to uncongested transport paths. The probability of a neighboring cell being connected to an uncongested transport path correlates to the system gain for proactive congestion avoidance. The level of system gain attainable is highly dependent on how the network is built, in terms of cell density, transport topology and technology. Urban areas, for example, tend to exhibit high numbers of cells within reach of a UE. As a result, the potential for improved system gain is high in situations where the cells have diverse transport paths. Holistic handover decisions are thus formed on the basis of transport congestion together with the typical signal strength and neighboring cell information – all of which are weighted. By including transport utilization information, more informed handover decisions can be made, which together with an abstraction of the relevant transport topology enables a cell to find a suitable neighboring cell to handover to. The benefits of RTI for this use case can be summarized as: by using congestion information from the transport domain, the radio domain can place user traffic optimally across radio cells, from a combined point of view of radio and transport characteristics. Figure 3 illustrates an example of this proactive congestion avoidance, where the second mile link is the congested part. On a high level, the benefit for this use case relates to the number of additional users or traffic for which the QoE requirements can be met in relation to the available radio resources (such as spectrum and radio equipment). In this case, RTI can be used to handover traffic generated by users in a cell with congested transport to another cell within the coverage area that has uncongested transport. As traffic is moved away from the congested cell, RTI has a positive impact on users that remain connected to the original cell – users that cannot be handed over to an uncongested cell because they are not within coverage area, or cannot be handed over for other reasons. This positive impact results from the load drop in the original congested cell as proactive handover actions are taken. The potential gain for RTI can be measured by the increase in users at or above the desired QoE level compared with a network without RTI. Naturally, actually calculating the gain depends on the specific network case and needs to consider factors such as the utilization of congested/
The transport network can prevent unfairness by rate-limiting selected traffic types. An example of this approach for fairness is illustrated in Figure 5, which shows a traditional method that will exhibit unfairness, and an enhanced RTI method that ensures fairness. RTI benefit and RTI gains for this use case can be formulated in the same way as for the previous cases.

**Example use case 2: optimized load-balancing**

This use case addresses transport, and how it can make better use of available resources by obtaining relevant information from radio. As mentioned, the transport domain lacks granularity, and so the proposed solution is to announce traffic information to the transport network in such a way that existing standardized implementations of the GTP or IPsec protocols require no change. The additional information allows the transport network to optimally load-balance traffic over equal cost multipaths (ECMPs) or a LAG. In addition, the proposed solution will work equally well for traffic that is encrypted as for non-encrypted traffic.

The RTI gain for the second use case is built on the assumption that load balancing traffic in an optimized fashion results in an overall improvement of QoE and better utilization of transport resources, see Figure 4.

**Example use case 3: fairness**

Today, transport networks cannot distinguish between best-effort (BE) traffic originating from different radio access types. The radio-access domain has more granular QoS profiles, but mapping them onto the transport domain will significantly increase the complexity of the QoS solution for the transport network operator. The result: BE-marked traffic will experience the same, shared per-hop behavior for all access technologies, which may cause starvation of one or several RATs. By instead exchanging traffic information and bandwidth ratios, the transport network can prevent unfairness by rate-limiting selected traffic types. An example of this approach for fairness is illustrated in Figure 5, which shows a traditional method that will exhibit unfairness, and an enhanced RTI method that ensures fairness. RTI benefit and RTI gains for this use case can be formulated in the same way as for the previous cases.

**The building blocks**

Based on the example use cases, Figure 6 illustrates the building blocks of the RTI solution. The main building blocks are generic to communication systems and include radio access, transport and the packet core.

**Radio access**

This part of the system includes multi-standard mobile broadband systems such as 2G/EDGE, 3G/WCDMA, and 4G/LTE.
4G/LTE (with 5G coming in the future) – together with their controller functions like RNC and BCS.

Transport
This part of the system includes routers and switches (such as IP/MPLS and L2) and physical layer components (such as microwave and optical transport) together with their respective optional controller components. Specifically for the transport domain, such an optional controller component is illustrated in Figure 6 by the SDN controller (SDNc).

Packet core
This part of the system includes connectivity and routing/forwarding gateways (S/PGW), multimedia control nodes (such as MMEs) as well as policy entities (such as the PCRF). As the packet
core contains relatively few elements compared with radio access, scalability benefits can be gained by sharing information between the transport controller and the packet core.

Specifically, RTI-application functions are included in radio-access, transport and, optionally, the packet-core networks in order to:

1. gather the information related to its domain;
2. handle the information flow between the transport and radio domains; and
3. make intelligent decisions based on the shared information.

The RTI application consists of distributed RTI entities corresponding to the radio access, transport and core networks, and offers the following benefits:

- maximized flexibility and scalability; and
- utilization of future technologies, such as advanced analytics, self-organizing functions, and 5G mobile broadband.

Summary and conclusions
This article outlines the background, motivation, example use cases and building blocks of RTI – a new concept for sharing information between radio and transport domains to optimize QoE.

By illustrating the concept through selected example use cases, the gain becomes clear. Proactive congestion avoidance, for example, enables the radio domain to make more intelligent handover decisions, as it includes congestion information provided by the transport domain in the decision-making process. The result: improved QoE with the existing set of available radio access and transport network resources.

The other use cases – load balancing and fairness – illustrate how the information from the radio domain facilitates better utilization of available transport resources. In the case of optimized load-balancing, more finely grained information provided by the radio domain enables the transport domain to optimally redistribute traffic, and thereby ensure better utilization of the network. In the case of fairness, the information from the radio domain is used to allocate bandwidth in IP routers for mobile traffic carried by different generations fairly. For each use case, an outline of the RTI benefit principles has been provided.

In summary, RTI is an innovative concept that enables a significant improvement in QoE for mobile users in the context of the example use cases, as well as enabling more optimal utilization of network resources.

References
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