TECHNOLOGY WHITE PAPER

Network Sharing in LTE

Opportunity & Solutions

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1. Market overview

Mobile Service Providers (MSP) are facing new challenges. On one hand, the number of data subscribers as well as the data usage per subscriber is exploding. On the other hand the generated revenue does not increase the same way. These challenges are depicted in Figure 1.

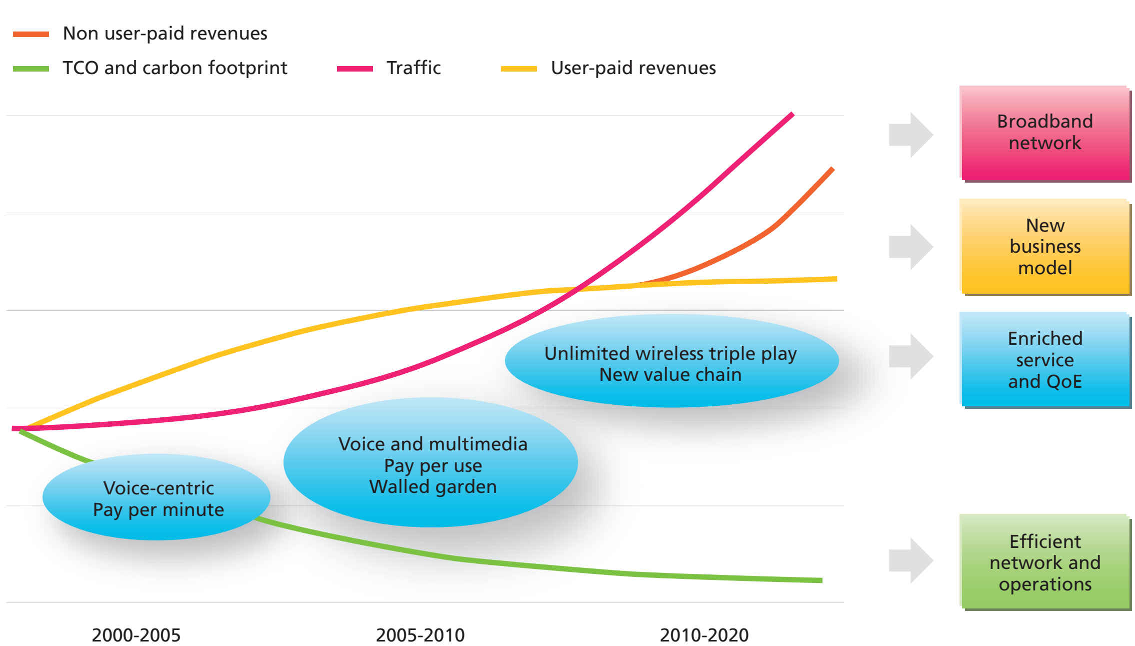
Data traffic explosion is explained by both a change in the way we communicate and a rapid change in wireless devices, enabling anytime, anywhere multimedia communications. Millennials, loosely defined as 11 to 30 years-olds, are redefining the way consumers interact in both a social and business setting. They intuitively and rapidly adopt new services and devices. They not only text, but they also download music and videos, play games, and use social networking sites such as Facebook and MySpace to stay socially connected. With their high Internet content consumption, this group more than doubles the average subscriber's mobile data usage. Furthermore, as Millennials enter adulthood and the workforce, they are also changing the way the enterprise communicates.

Rapid changes in wireless devices, enabling anytime, anywhere, multimedia communications, have also played a major role in the data explosion. Some wireless devices are being integrated with cameras, video recorders, iPods, and media players. Others, like e-Readers, are not being integrated at all, but rather customized to deliver a high quality of experience for only one particular application. All these devices, however, are simplifying multimedia communications, enabling it to flourish.

Revenue generated by the data traffic explosion will not increase the same way because the subscribers are used to benefit from broadband access at low price.

This market evolution poses new challenges to MSP. They need to deploy wireless networks able to sustain more capacity while reducing the total cost of ownership and finding new business models generating new sources of revenue. In this context, network sharing is a way to reduce CAPEX and OPEX.

Figure 1. Mobile Service Providers new challenges.



1.1 Opportunity for network sharing in LTE

Network sharing is not new in the wireless business. Operators throughout the world already share transmission towers and sites. In France, Orange shares 40% of sites with other operators in rural areas. Telefonica and Vodafone have announced Europe's first multi-market network sharing deal. The partners will share sites and equipments, where appropriate in the UK, Ireland, Germany and Spain. However most of network sharing agreements today are limited to passive sharing in which operators share the sites and civil engineering elements. Active network sharing where operators share base stations, antennas or even radio network controller is not widely deployed in 2G and 3G.

Will this change with LTE?

Will active sharing exist with LTE?

Several facts can enlighten the reflection:

- Cost saving is still an incentive even if estimates vary on what operators can save by sharing infrastructure. This can be a catalyst especially in the global economic downturn.
- Mobile network operators have learnt from sharing experiences with 3G and attitudes towards sharing are obviously changing.
- LTE deployments will require major investments. And even if LTE will enable high-speed services that promise a flood of traffic, the revenue they generate will not likely increase the same way, especially because the subscribers are used to benefit from broadband access at a low price.
- Sharing mechanisms have been built into the LTE standard from the beginning.
- LTE is designed with a modern IP-based architecture in mind and IP-based technology is a more flexible platform than legacy technologies. It also provides standard mechanisms to interlink with other IP-based systems.
- Some countries are pushing to reduce the digital divide (e.g. Digital Britain initiative in the UK requesting at least a network speed of 2 Mbits/s in every home). This kind of initiative combined with the availability of the 800 MHz band and the fact that it is not economically viable that each operator deploys its own network in rural areas could be an important incentive to deploy shared LTE networks in rural areas. This could lead to the emergence of pure LTE wholesale players deploying the shared eUTRAN in rural areas, each CN operator deploying its own eUTRAN in dense urban areas where capacity demand justifies a dedicated eUTRAN per CN operator (refer to 1.2.1).
- In certain cases sites constraints can lead to a eUTRAN sharing solution (e.g. difficulties to install new antennas).

However, regulators in most countries embrace passive sharing as a mean to avoid network duplication, reduce upfront investment costs and minimize the impact on the environment, while creating incentives to roll out services in underserved areas. On the other side active sharing remains a more contested issue. Their argument is that it could lead to anti-competitive conduct in prices and services. For example national roaming in France is only allowed in "white zone[1]" areas. On the contrary Nordic countries are more open to network sharing.

Whether LTE will drive infrastructure sharing to a new height remains to be seen. However as mentioned above there are a lot of factors that tend to think that there are opportunities for tighter network sharing in LTE. This is also reflected by feedback from customers.

[1] A « white zone » is an area with a low density of population where it is not economically viable that each operator deploys its own network.

1.2 Customer cases

This section aims at illustrating use cases for eUTRAN sharing already encountered.

1.2.1 LTE capacity wholesaler

In one European country a company plans to become a pure LTE capacity wholesaler. This company plans to deploy a broadband network using the LTE technology in rural areas and wholesales network capacity to mobile and potentially fixed network operators. Mobile network operators will deploy their own LTE network in dense urban areas where capacity demand justifies that operators invest in their own LTE network. Those mobile network operators will also be connected to the shared eUTRAN managed by the wholesaler to provide mobile broadband services in rural areas.

The market situation…

- An initiative of the government sets out the importance of the Digital Economy to the nation's economic future and how it will drive future industrial capability and competitiveness. In particular the government sets a target of Universal Service Broadband Commitment at 2Mbps by 2012.
- Significant demand in rural areas for good quality broadband.
- Auction for both the 800 MHz and the 2.6 GHz bands is planned in Q2-2010. The 800 MHz band, due to its propagation characteristics, will be used for rural deployments.

… and the company assets (i.e. radio sites all over the country) justify the pure wholesale model.

It should be noted that the wholesaler does not plan to own its own spectrum but foresees a business model in which the wholesaler rents the spectrum from spectrum owners and in return sells LTE wholesale capacity.

1.2.2 LTE network sharing Joint Venture (JV)

A joint venture created by two operators is today managing a shared 3G radio access network between those two operators. Based on this experience, the two operators have decided to also share their 2G and LTE access networks. The main drivers are harmonization of all their radio access networks and cost reduction.

Two main technical points were debated with these two operators:

- Which strategy to use for PLMN ID in the shared eUTRAN?

  Two alternatives were possible: PLMN ID of each operator is broadcasted or a common PLMN ID is broadcasted. As in LTE the UE shall support a list of PLMN IDs and a network selection process (refer to 2.1.2) Alcatel-Lucent promoted the broadcast of each operator PLMN ID on the air interface. This is fully compliant with the 3GPP eUTRAN sharing approach. To be noted that in 3G it is not mandatory for a UE to support a list of PLMN IDs. Hence in case of 3G UTRAN sharing a common PLMN ID is defined. This common PLMN ID is used by 3G UE not supporting a list of PLMN IDs.
- How traffic separation between operators is done in the shared eUTRAN?

  Traffic separation is done using VLANs (refer to 3.1.3). This allows to easily fulfilling one of the requirements of those two operators to be able to route each operator's traffic to their respective backhaul network as soon as possible.

1.3 Challenges for eUTRAN sharing

As explained above, network sharing is a way to reduce CAPEX and OPEX. However a successful network sharing deployment shall take into account the following challenges:

- Quality and service differentiation
  - An homogeneous QoS shall provided over the shared and the dedicated eUTRAN. Quality of Experience shall be the same for the subscribers.
  - Differentiation between partners will be at services and applications level.
- Regulation
  - Negotiation with the regulator to adapt license conditions could be needed.
- Commercial and legal aspects
  - If applicable, establishing a joint venture between sharing partners will be needed.
  - Agreement on a service level agreement, penalties, scope and duration shall be defined,
  - Agreement on the expenditure split and model shall be defined.

2. Standards perspective

Two technical solutions are presented in this document, namely National Roaming and eUTRAN sharing. They both allow the sharing of the LTE network even if they differ on the business and technical relationships between involved partners.

In the national roaming approach, as its name indicates, relationships between partners follow the well known roaming agreements model. Operators are not required to share any common network elements. Traffic from one carrier is carried over the network of another.

In eUTRAN sharing, a tighter business and technical relationship between partners is needed as operators share the active electronic network elements like base stations. A shared eUTRAN is connected to each operator core network.

2.1 Roaming and eUTRAN sharing in 3GPP

3GPP standards applicable to roaming and eUTRAN sharing are listed in the table below:

STANDARD	VERSION	SPECIFICATION DESCRIPTION
TS 23.401	V8.6.0	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access (Release 8)
TR 22.951	V8.0.0	Service aspects and requirements for network sharing (Release 8)
TR 23.251	V8.1.0	Network Sharing; Architecture and functional description (Release 8)

2.1.1 Roaming in 3GPP

3GPP has defined two approaches for roaming in LTE, namely the home routed traffic and the local breakout approaches. They are depicted in Figure 2 and Figure 3 respectively. These two approaches differ on the location of the PGW. In the home routed traffic the PGW is located in the home network. Thus subscriber's traffic is routed up to the home network. In the local breakout the PGW is located in the visited network. Subscriber's traffic is routed locally at the visited network level. In both approaches the HSS is located in the home network.

National roaming can be seen as an alternative to eUTRAN sharing. However, the main disadvantage of national roaming is that the PLMN ID of the visited network is broadcasted on the air interface. So this is not transparent for the subscribers in roaming situation. Most of the time national roaming is used as a way to support geographical split agreements between operators. Each operator deploying its own network and using its own spectrum. So in case of national licenses, the whole available spectrum is not used. For those reasons, national roaming is more appropriate either in some markets where licenses are allocated on a regional basis or for early LTE deployments between operators wishing to provide a broad LTE coverage from the beginning but who do not want to establish long-term relationships.

National roaming is not described in details in this document.

Figure 2. Roaming in LTE with home routed traffic.

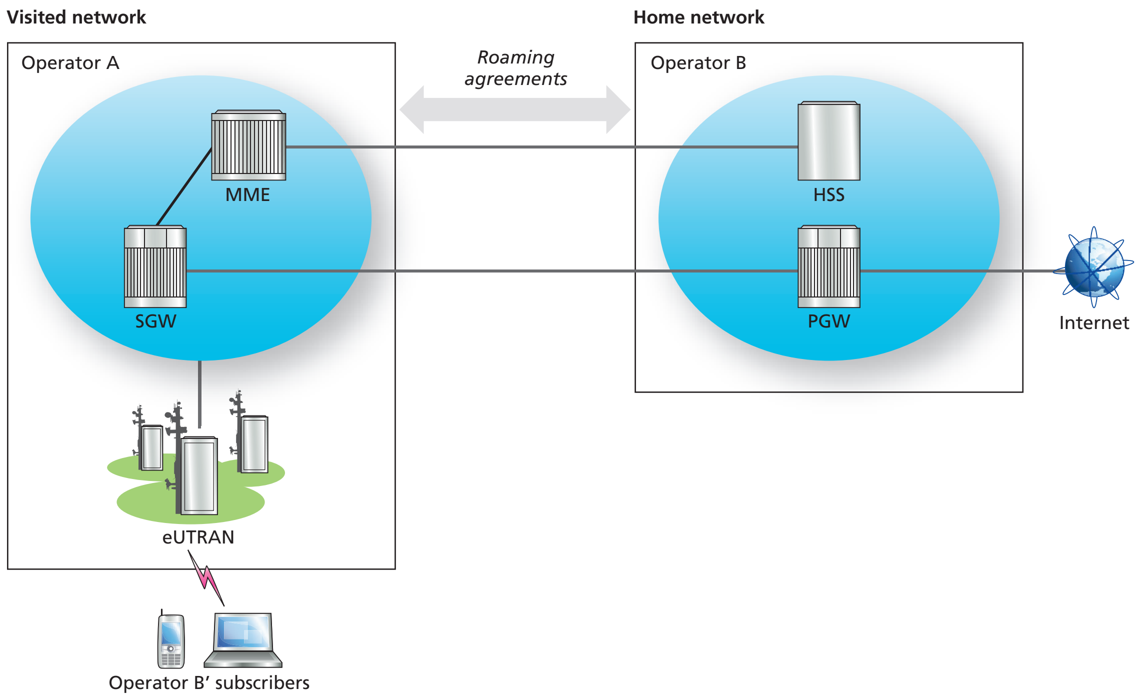
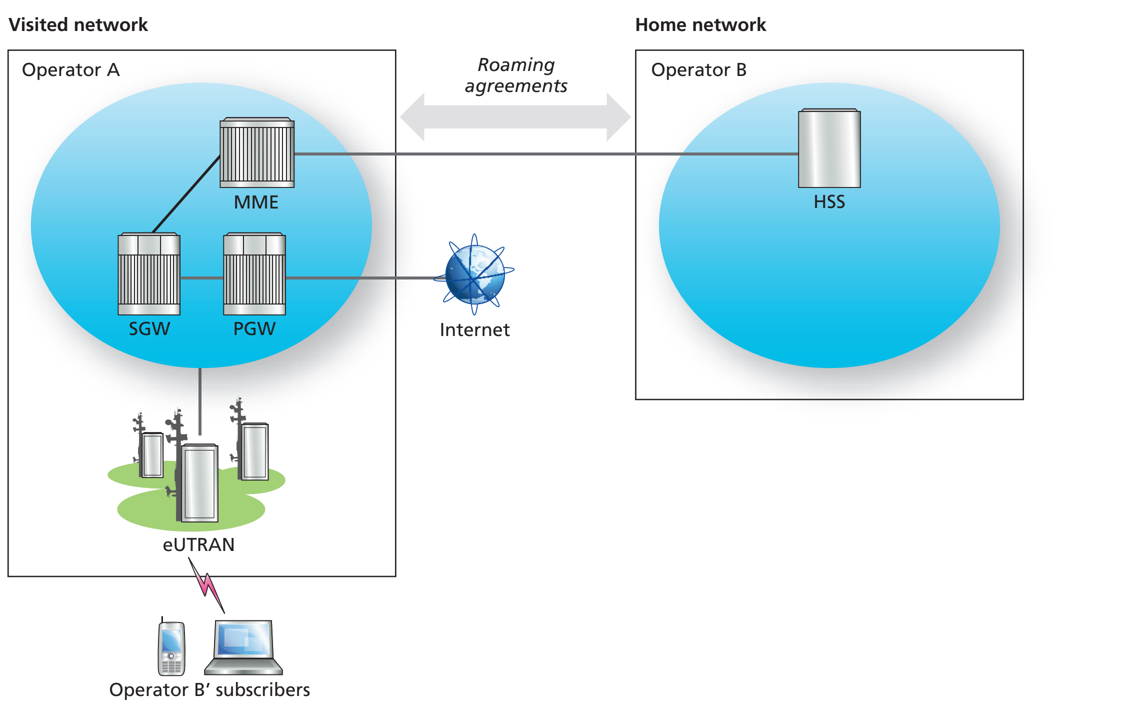


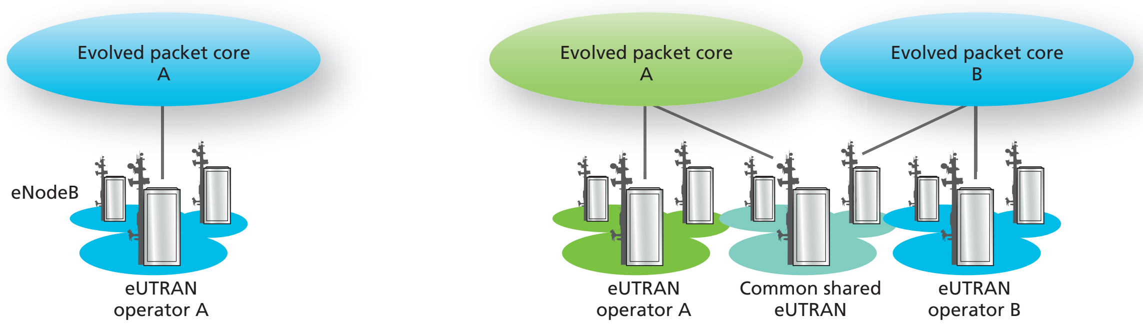
Figure 3. Roaming in LTE with local breakout



2.1.2 eUTRAN sharing in 3GPP

In the eUTRAN sharing approach the LTE eUTRAN is common to several mobile network operators and shared between them. Several CN are connected to the common shared eUTRAN. This is depicted in Figure 4. The left side of Figure 4 shows the non sharing approach where both the eUTRAN and the EPC belong to a single operator. In this case the eUTRAN is connected to a single EPC (i.e. operator A's EPC). The right side of Figure 4 shows the eUTRAN sharing approach where the eUTRAN is common to several mobile network operators and connected to several EPC, one EPC per mobile network operator. As shown on the figure, each mobile network operator can have its own eUTRAN (i.e. a dedicated eUTRAN) in addition to the common shared eUTRAN shared with other mobile network operators. For instance, each mobile network operator has its own eUTRAN in dense urban areas and share a common eUTRAN in areas (e.g. rural areas) where its is not economically viable to deploy one eUTRAN per operator.

Figure 4. Non shared eUTRAN and shared eUTRAN.



In addition to the shared and dedicated eUTRAN each mobile network operator can have its own 2G and 3G radio access network (not shown on the figure).

3GPP has defined two approaches for the eUTRAN sharing:

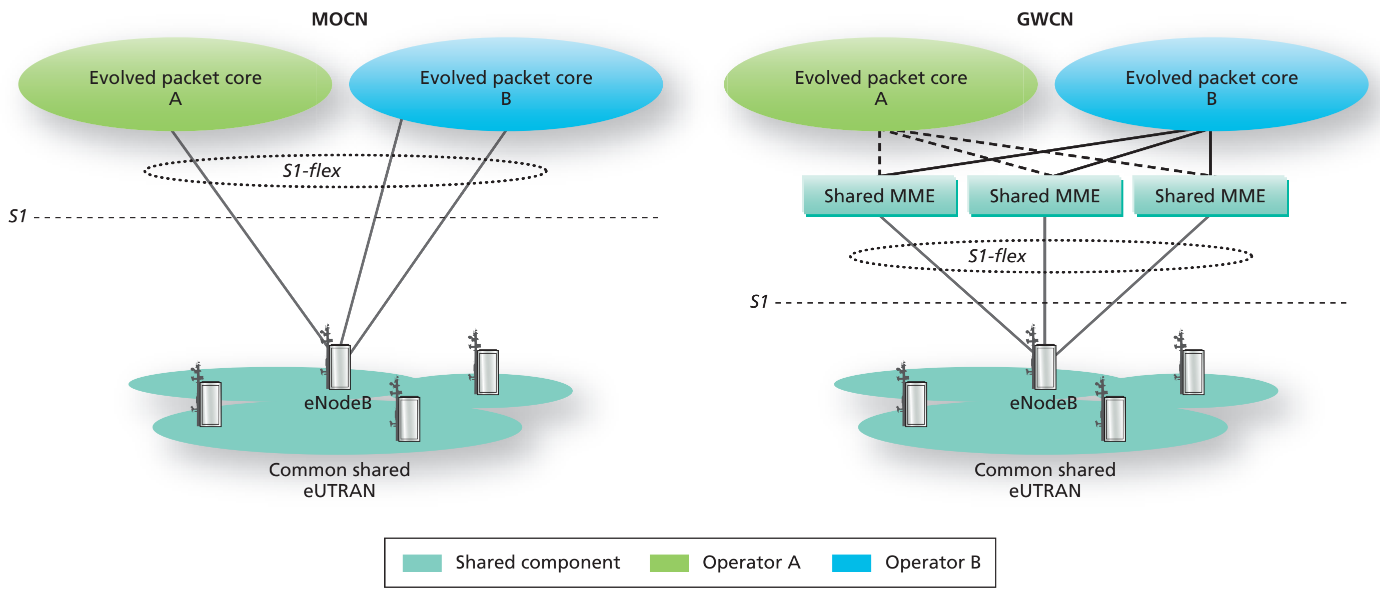
- The Multi-Operator Core Network (MOCN) approach
- The Gateway Core Network (GWCN) approach.

These two approaches are depicted in Figure 5.

In the MOCN approach the shared eUTRAN is connected to several CN via the S1 interface. Each mobile network operator has its own EPC. Thus the MME, the SGW and the PGW are not shared and are located in the different CN. As shown in the picture the S1 flex allows the eNodeB to be connected to the different CN. It also allows connecting the eNodeB to several MME and SGW in a given CN. Thus, allowing load balancing to be supported between MME and SGW of a given CN.

In the GWCN approach, contrary to the MOCN approach, the MME is also shared between the different mobile network operators.

Figure 5. The MOCN and GWCN approaches for eUTRAN sharing.



The following table provides a high level comparison of those two approaches.

	MOCN	GWCN	COMMENT
Interworking with legacy networks	+	-	To support inter-RAT mobility, MME needs interfaces with legacy networks (i.e. SGSN). Sharing the MME leads to a tighter integration between the shared eUTRAN and each CN operator.
Support of voice service with CS fallback	+	-	CS fallback needs the support of the SGs interface between MMEs and the MSCs. Sharing the MME leads to a tighter integration between the shared eUTRAN and each CN operator.
Support of voice service with IMS	=	=	Support of IMS is the best and future solution for voice over LTE.
Support of roaming	+	-	In roaming MME in visited network needs to interact with HSS in home network. Having a shared MME is a drawback as HSS address of each roaming partner needs to be define in shared MME for each CN connected to the shared eUTRAN.
Cost	-	+	Sharing the MME shares the cost. However this depends on the context.

Due to the pros and cons presented in the above table the MOCN approach will be implemented first.

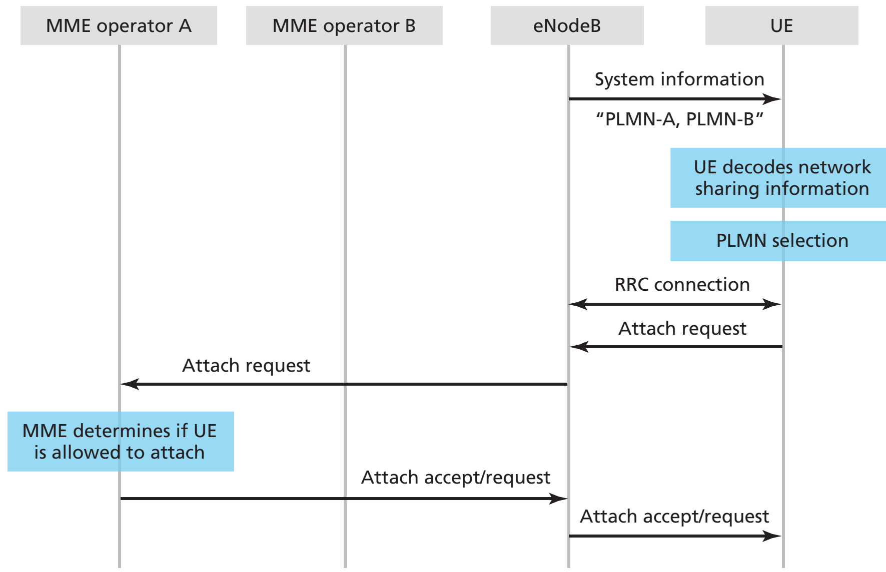
Network selection in eUTRAN sharing

PLMN selection in MOCN is composed of the following steps:

- PLMN IDs of the different mobile network operators are broadcasted on the air interface in the System Information Block (SIB).
- The User Equipment (UE) decodes system information and performs the PLMN ID selection process.
- The selected PLMN ID is specified in RRC connection procedure.
- The eNodeB uses the selected PLMN ID to forward the attachment request to an MME belonging to the correct CN.

This scenario is depicted in Figure 6.

Figure 6. PLMN selection in MOCN.



A 3GPP complaint LTE UE shall support the eUTRAN sharing feature (i.e. a list of PLMN ID).

3. Alcatel-Lucent solution for eUTRAN sharing and key differentiators

The Alcatel-Lucent end-to-end solution for eUTRAN sharing fulfils the specific requirements that apply to a radio access network sharing configuration:

- Flexibility in spectrum management. Both shared and dedicated spectrum approaches are supported.
- Flexibility in capacity sharing and end-to-end QoS control between operators connected to the shared eUTRAN.
- Traffic separation between operators.
- Support of accounting information reflecting, for each operator, the usage of the shared network resources.

The following sections describe in details how those different points are supported.

3.1.1 Spectrum usage in eUTRAN sharing

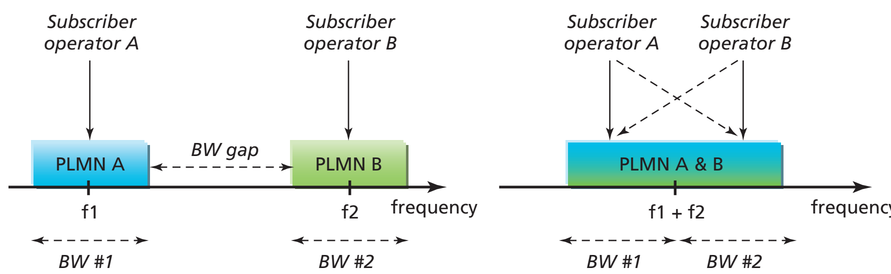
Two strategies are supported for the spectrum usage in eUTRAN sharing:

- Spectrum can be shared between CN operators
- Spectrum can be dedicated per CN operator.

Those two approaches are depicted in Figure 7 with two operators as an example. In a shared spectrum approach subscribers of operator A and operator B can use the full spectrum of operator A and B. In the dedicated spectrum approach subscribers can only get network access using their respective operator's spectrum.

Sharing spectrum is more efficient as this does not create a strict split of the radio resources between operators. Strict split means that if subscribers of one operator are using the whole bandwidth of this operator then no additional subscribers of this operator can enter the network in this cell even if there is still bandwidth available from the other operator. Sharing spectrum also reduces the overhead and allows supporting higher peak rate as the available bandwidth is more important.

Figure 7. Shared spectrum / dedicated spectrum



For this reason shared spectrum approach will be implemented first.

In LTE the Inter-Cell Interference Coordination (ICIC) function is a powerful technique to improve performances at cell edge by reducing interferences. The X2 interface between eNodeBs is used to exchange interference related information between eNodeBs. If X2 interface cannot be used between the shared eUTRAN and dedicated eUTRANs, most of the time this will be the case, then static configuration done at the network management system level (in the shared eUTRAN and dedicated eUTRAN) can be done to still benefit from the capacity improvement provided by the ICIC function.

Support of shared spectrum for optimizing radio resources usage

3.1.2 QoS in eUTRAN sharing

3.1.2.1 End-to-end QoS model

The goal of the end-to-end QoS model is to control the amount of traffic flowing in the eUTRAN in order to:

- Fulfill the Service Level Agreement (SLA) requirements between the eUTRAN provider and the different CN operators.
- Protect the eUTRAN resources from uncontrolled traffic flowing into the eUTRAN which would result in uncontrolled congestion.

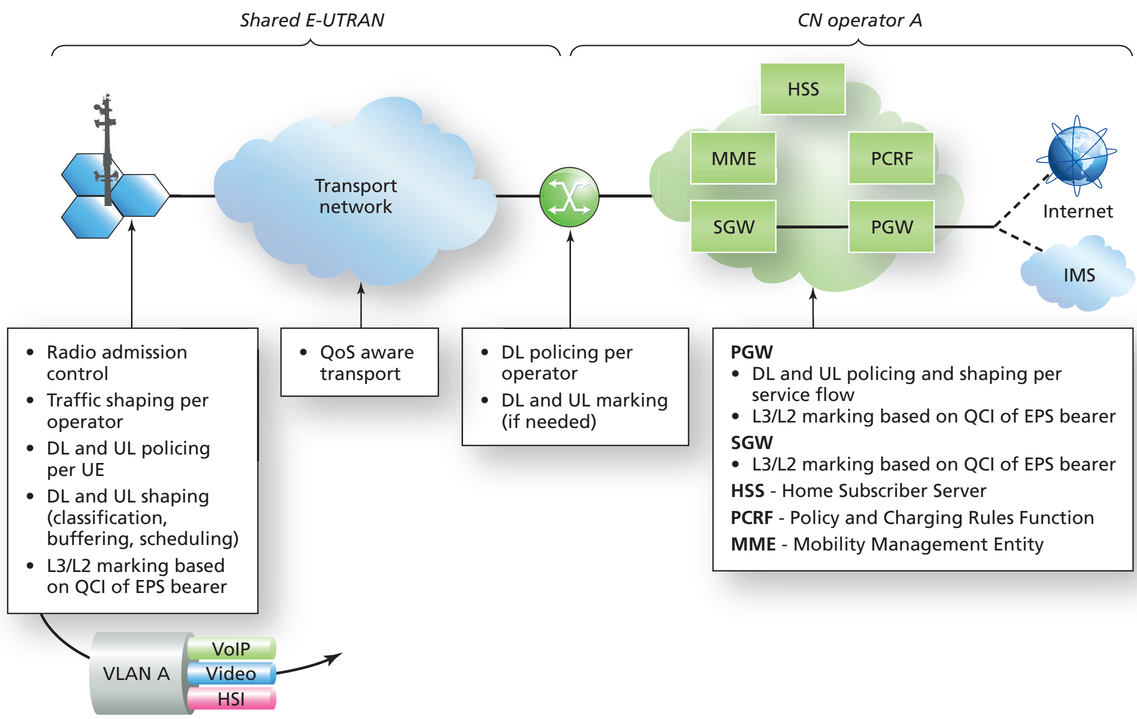
This is especially true in case of a pure wholesaler selling eUTRAN capacity to different CN operators. An excess of traffic of one CN operator could lead to a violation of the SLA of other CN operators sharing the eUTRAN. In addition the wholesaler needs to guarantee a fair access to the eUTRAN resources by the CN operators sharing the eUTRAN.

Several mechanisms are used to control the QoS within the shared eUTRAN:

- At the eNodeB level
  - ¬ Call Admission Control.
  - ¬ Policing per radio bearers.
  - ¬ Traffic shaping per operator.
  - ¬ Marking based on QoS Class Id (QCI) specified at radio bearer establishment.
- At the eUTRAN egde router (refer to 3.2) IP QoS features can be used to
  - ¬ Perform policing and shaping at aggregate level to control the amount of traffic coming from each CN operator in DL.
- Within the transport network between the eNodeB and the eUTRAN edge router
  - ¬ The transport network shall support QoS to provide the correct priority to IP packets or Ethernet frames marked by the eUTRAN edge router or the eNodeB.

These QoS features are depicted in Figure 8.

Figure 8. End-to-end QoS architecture in eUTRAN sharing (MOCN).



End to end QoS model to ease Service Level Agreements enforcement by controlling network resource usage per CN operator

3.1.2.2 Capacity sharing between CN operators

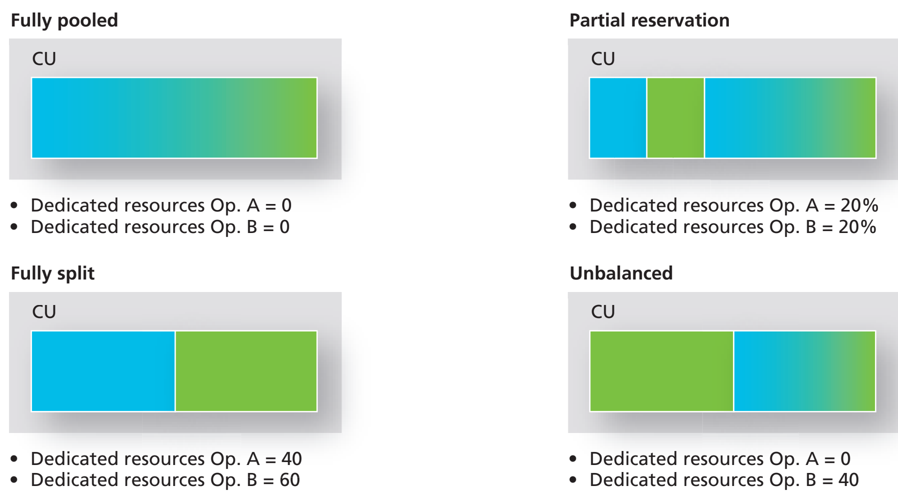
As radio resources are scarce resources it is important to provide flexible mechanisms to control the usage of these resources. In case of eUTRAN sharing several CN operators will compete for radio resources. This dimension shall be taken into account by the mechanisms controlling access to radio resources.

The Alcatel-Lucent solution supports a very flexible way of controlling radio network resources. Indeed strategy can be different from one operator to another and will evolve over time. Figure 9 depicts the different approaches supported for resources sharing at the eNodeB level between CN operators. Strategies range from "fully pooled" to "fully split":

- *Fully pooled:* this model allows a complete sharing of all radio resources between the different CN operators. There are no resources reserved per CN operator. In the extreme case subscribers from one CN operator can use all the resources, a fair access to resources for each CN operator cannot be guaranteed. This strategy can be useful at the early staged of LTE deployments in which the number of subscribers being relatively low compared to the radio resources available.

- *Fully split:* this model allows a strict reservation of resources per CN operator. If resources reserved for a given CN operator are fully used then a network attachment request or a new connection request from a subscriber of this given CN operator will be rejected even if resources reserved for other CN operators are not fully used. This strategy is more adapted in areas where there is a risk of having subscribers of a given CN operator using all the radio resources. Thus a fair access to resources shall be enforced.
- *Partial reservation:* this model allows to reserve resources per CN operator and to leave a part of the resources unreserved. Thus a fair access to resources can be enforced and non reserved resources can be used when needed by the different subscribers. This is probably the best comprise in resources sharing.
- *Unbalanced:* this model is a sub case of the "partial reservation" model in which resources are reserved for few CN operators but not for every single CN operator.

Figure 9. Capacity sharing between CN operators at eNodeB



The strategy is configured at the XMS level (Network Management System of the eUTRAN) and is per eNodeB. Parameters used to define capacity per CN operator are the same as the ones used for the configuration of the call admission control.

Flexible solution for capacity sharing per CN operator at eNodeB

3.1.2.3 Resource usage information per CN operators

In a shared eUTRAN configuration it is important for the shared eUTRAN provider to get information on network resource usage per CN operator. This information will be the basis for checking that SLAs are in compliance with what has been defined between partners.

Resource usage information per CN operator can be obtained at two levels:

- The eNodeB generates performance management counters per PLMN-ID. They include in particular data traffic related counters per QoS. Those counters are collected at the Network Management System level.
- The eUTRAN edge network element provided by Alcatel-Lucent is also able to collect accounting information per CN operator. Refer to section 3.2 for more information.

Resource usage information available per CN operator to ease SLA compliancy checking

3.1.3 Traffic separation between CN operators at eNodeB

Traffic separation between CN operators within the shared eUTRAN is done using VLANs. The solution supports the following configuration at the eNodeB:

- One VLAN for S1 (S1-MME & S1-U) and X2 interfaces per CN operator.
- One VLAN for S1 (S1-MME & S1-U) interface per CN operator and one VLAN for X2 interface per CN operator.

In all cases a dedicated VLAN for OAM traffic can be defined.

3.1.4 Mobility in eUTRAN sharing

One key point to support mobility is the definition of a neighbor cells list. This neighbor cells list contains neighbor cells information that is useful for both UE in connected mode and in idle mode. A UE in idle mode uses the neighbor cells information to perform cell reselection while moving around. For UE in connected mode neighbor cells information is used by the eNodeB for UE redirection to the right target cell and for handovers.

As far as mobility is concerned, the specificity related to a shared eUTRAN configuration is that several PLMN IDs are involved. And neighbor cells list depends on the selected PLMN ID. The solution will support PLMN specific neighbor information. This implies that the selected PLMN ID needs to be transferred from the source eNodeB to the target eNodeB during the handover. This information will be used by the serving eNodeB to build the neighbor cells list to be provided to the UE.

Several mobility scenarios need to be considered. They are depicted in Figure 10:

- *Case 1:* intra-LTE mobility within the shared eUTRAN.

  Both source and target eNodeB belong to the shared eUTRAN. Both S1 and X2 based handovers are possible. Selected PLMN ID is provided to target eNodeB during handover either via S1 or X2 interface (*Handover Restriction List IE*).
- *Case 2:* intra-LTE mobility between the shared eUTRAN and a dedicated eUTRAN.

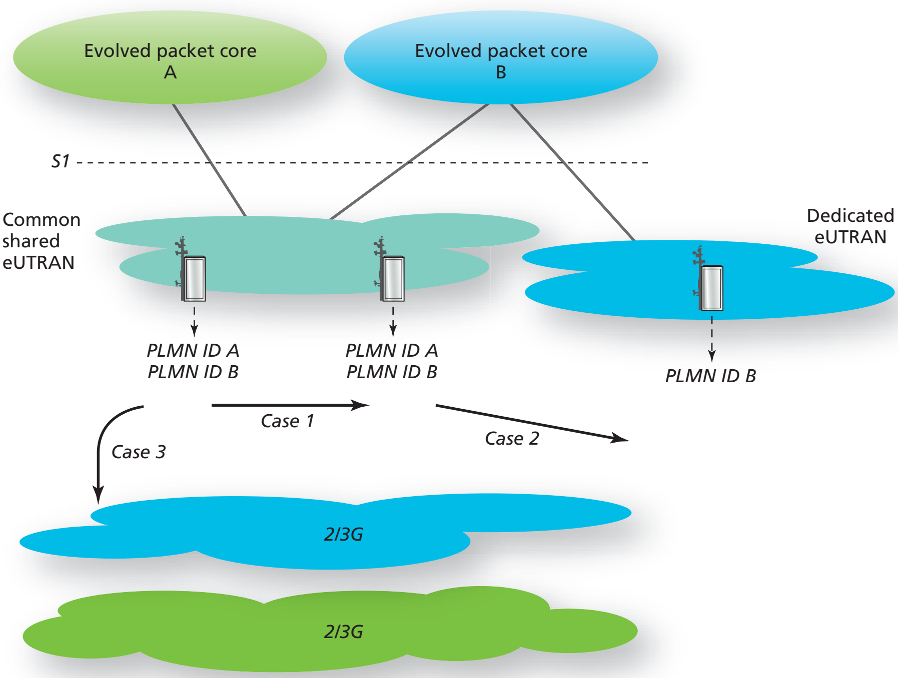
  Source eNodeB is at the edge of the shared eUTRAN. Neighbor cells belong to a dedicated eUTRAN. Potentially there can be several dedicated eUTRAN at the edge of the shared eUTRAN (e.g. one dedicated eUTRAN per CN operator). If dedicated eUTRAN and shared eUTRAN belong to different entities (with different IP routing plans) handovers will be S1-based. Source eNodeB in the shared eUTRAN needs to know neighbor cells information related to eNodeB in the dedicated eUTRAN and will use this information and the selected PLMN ID to build the neighbor cells list to be provided to the UE.
- *Case 3:* inter-RAT mobility between the shared eUTRAN and dedicated 2G or 3G networks.

  Same as case 2 except that neighbor cells are 2G or 3G cells of a dedicated 2G or 3G network.

Idle mode mobility in eUTRAN sharing

Idle mode mobility is controlled by absolute priorities of different eUTRAN frequencies or inter-RAT frequencies provided to the UE. In case of eUTRAN sharing as UEs belong to different PLMNs, the solution will support PLMN specific neighbor information and priorities for UEs in idle mode. This will be provided to the UE using the *idleModeMobilityControlInfo* IE in *RRCConnectedRelease* message.

Figure 10. Mobility scenarios in eUTRAN sharing



3.1.5 Voice service in eUTRAN sharing

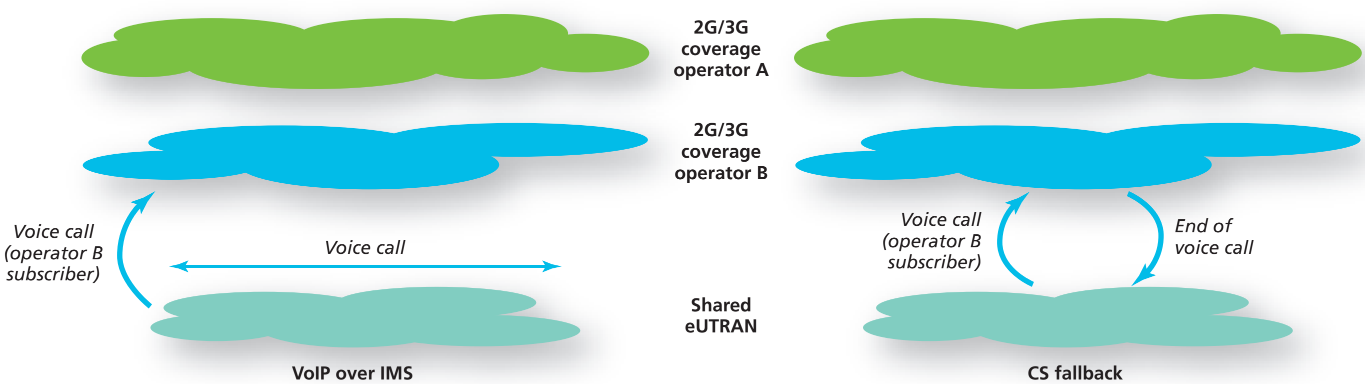
3GPP has defined two approaches for the support of voice over LTE, CS fallback and VoIP using the IMS.

In CS fallback, when a UE is under overlapping LTE and GERAN/UTRAN coverage the UE is registered in both the LTE network and the CS domain. When a voice call (either UE initiated or UE terminated) needs to be established a handover to the CS domain (either 2G or 3G) is done. Depending on the UE capabilities on one side and the 2G and 3G networks capabilities on the other side, a PS handover can also be done to continue the data session on the 2G or 3G PS network in parallel to the voice call. This implies that the eNodeB needs to know the 2G/3G neighbour cells information to be able to trigger the handover to the CS domain to setup the call.

In VoIP over IMS, the call is setup using a LTE connection. Voice call continuity is supported using the LTE handover procedures. Handover to the CS domain needs only to be done at the edge of the LTE network using SRVCC techniques. The call is anchored in IMS in this approach.

Both approaches can be supported in eUTRAN sharing. As explained above, the support of CS fallback requires that each eNodeB of the shared eUTRAN knows the 2G and/or 3G neighbour cells information for each CN operator to be able to trigger the handover to the CS domain to setup the voice call. For the VoIP over IMS approach only 2G and/or 3G neighbour cell information at the edge of the shared eUTRAN needs to be known. In addition if VoIP over IMS is also used on the 3G PS network then a standard PS handover between LTE and 3G provides service continuity for VoIP, there is no need of SRVCC in this case.

Figure 11. Voice service in eUTRAN sharing



Even if both CS fallback and VoIP over IMS are supported in eUTRAN sharing, VoIP IMS is the preferred approach as this drastically reduces the amount of network information (i.e. neighbor cells information) to be known by the shared eUTRAN provider.

3.2 End to end network architecture for eUTRAN sharing

This section provides two examples of end-to-end network architectures for eUTRAN sharing. They differ on how the interconnection is done between the shared eUTRAN and the CN operator networks. Interconnection is done at layer 2 in the first example and at layer 3 in the second one. Using a layer 3 or a layer 2 connection between the shared eUTRAN and the CN operator networks is really a case by case choice based on the customer network.

These are just examples aiming at highlighting the main principles. Final network architecture will depend on customer networks and requirements.

The main principles driving the end-to-end network architecture depicted in Figure 12 and Figure 13 are:

- IPSEC is used to secure the S1 interface between the eNodeB and each CN operator's network.
- VLANs are used for traffic separation at the eNodeB.
- IP addressing:
  - In shared eUTRAN one IP subnet is defined per VLAN per CN operator
  - Each eNodeB is configured with the VLAN to be used for each CN operator
  - IP@ defined at eNodeB for VLAN operator X is taken from the IP subnet defined within the shared eUTRAN for operator X.
- In case of eUTRAN sharing it is important to guarantee a fair access to the shared eUTRAN to the different CN operators. For that purpose the QoS features of the Alcatel-Lucent equipments can be used to control the amount of traffic per CN operator and the amount of traffic per forwarding class per CN operator (hierarchical QoS feature). Figure 12 shows the rate limiting for downlink traffic. This can also be done for uplink traffic as well but this is less critical than in the downlink.
- Capacity sharing among CN operator is also configured at eNodeB.
- For a wholesaler gathering accounting information per CN operator is also a key point as those accounting information will be the basis for charging each CN operator based on network resource usage. This can be done by using information provided by eNodeB (i.e. counters) and gathered at the XMS level or by using information provided by edge network elements (i.e. routers or switches).

Figure 12 shows an end-to-end network architecture based on layer 2 connections between the shared eUTRAN and each CN operator network. Possible configurations within the access and aggregation network are either one ELINE between the edge network element and each eNodeB per CN operator or one VPLS per CN operator.

Figure 12. An example for end-to-end network architecture for eUTRAN sharing

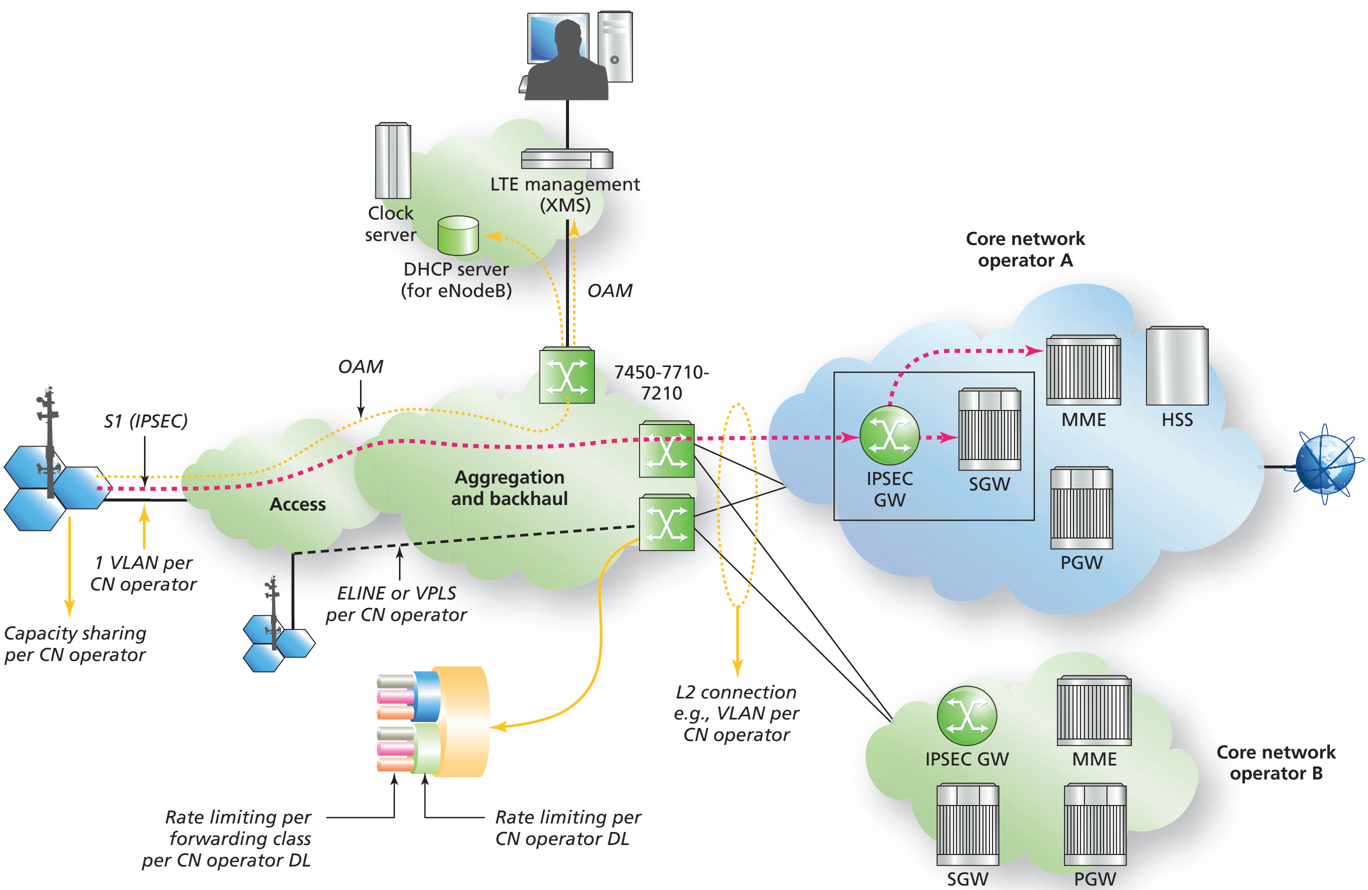
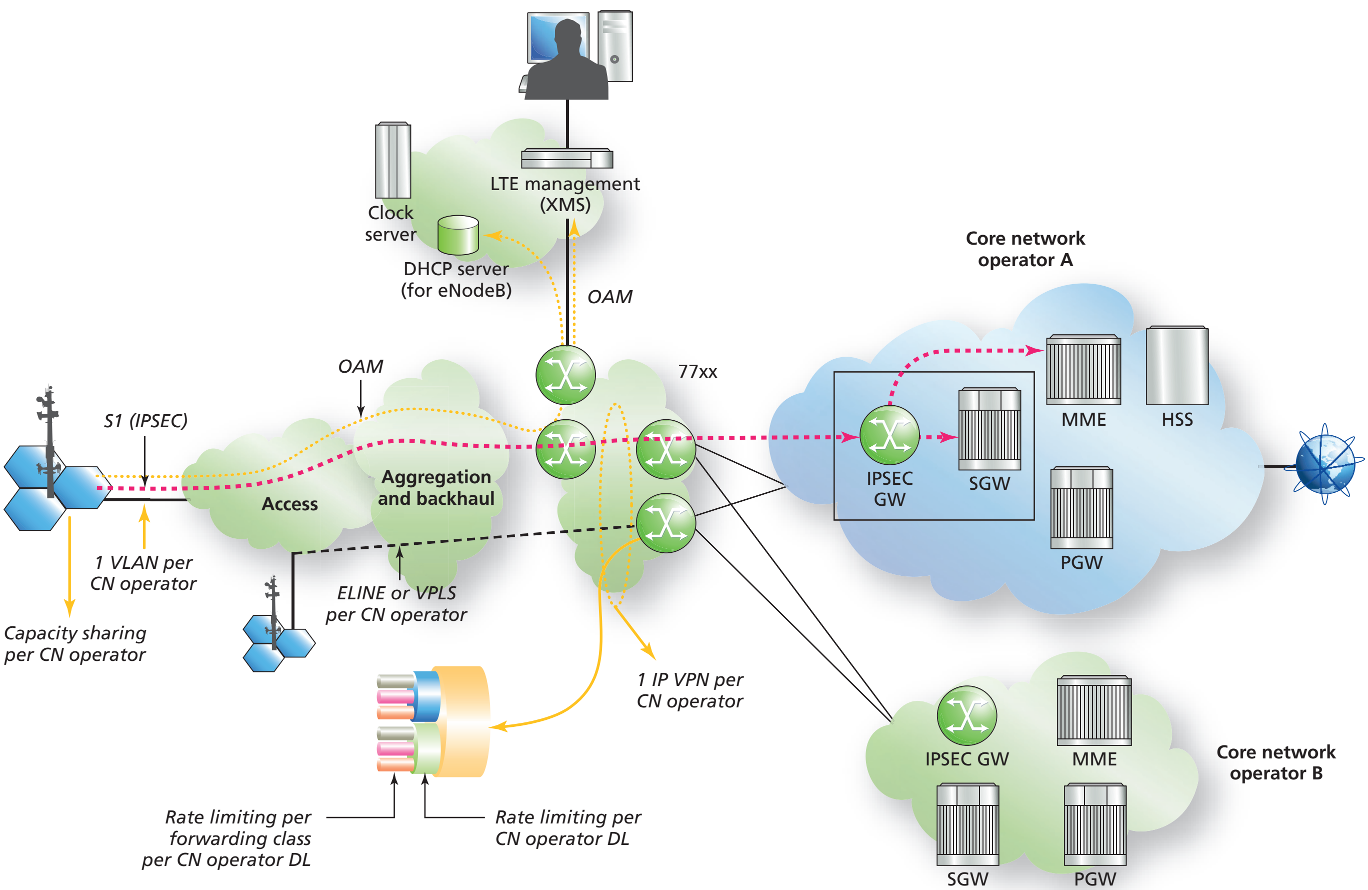


Figure 13 shows the end-to-end network architecture based on a layer 3 connection between the shared eUTRAN and each CN operator network. In this approach an IP VPN is defined for each CN operator. The IP VPN of each operator is configured to route the IP subnet defined within shared eUTRAN for associated operator.

Figure 13. An example for end-to-end network architecture for eUTRAN sharing



4. Acronyms

CN	Core Network
e-UTRAN	Evolved UTRAN
EPC	Evolved Packet Core
GWNC	Gateway Core Network
HSS	Home Subscriber Server
LTE	Long Term Evolution
MME	Mobility Management Entity
MOCN	Multi-Operator Core Network
MSP	Mobile Service Provider
QCI	QoS Class Id
QoS	Quality of Service
RAT	Radio Access Technology
SIB	System Information Block
SRVCC	Single Radio Voice Call Continuity

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