ALTICE LABS WHITEPAPER

Scope Management for LTE/EPC Implementation

July 2013

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Executive Summary

After all the studies and business cases done by a telecom operator for initial roll out of a new technology and network come the hard decisions.

The implementation of a commercial LTE/EPC service by an operator has impacts on almost every aspect of its operational ecosystem, implying a long list of issues to be dealt with and decisions to be made on how best to address those impacts.

The first batch of decisions includes the Business Objectives, decision “to go” and timing.

After, comes the second list of decisions related with Project Definition that defines scope: of the services to be delivered over LTE/EPC and of the issues to be addressed along the operational ecosystem. This set of decisions is known as the “services and network strategy”.

Then, a third batch of decisions addressing all the technical aspects that should be included on the technical specifications to be submitted to suppliers.

A fourth batch of decisions includes addressing the selection of suppliers and all negotial, legal and financial aspects for LTE/EPC network and service implementation.

Finally, a fifth batch of decisions corresponding to commercial service deployment: service profile, marketing, tariffs, customer support, distribution, sales and communication.

This document focuses on the second list of decisions addressed by operator on commercial LTE/EPC implementation, the ones related with project scope, so it is called “Scope Management”. The result of these decisions, as referred, is the “Services and Network strategy”.

The document is referred to a general operator, named OPERATOR through the document.

It includes the list of issues to be addressed by OPERATOR, discusses its scope, and provides some advice for smooth rollout based on Altice Labs field experience with LTE/EPC implementation.

The list of issues is organized according with impact evaluated from OPERATOR perspective:

- **Offer – Central aspect, critical impact:**
    - Service scope
        - Minimum set of services
        - Optional services
        - Service characterization
            - QoS
            - Handover
            - Throughput
            - Interconnection
            - Roaming
            - Tethering
- **Financial implications - Very high impact:**
    - Assets,
    - Licenses, frequencies and bandwidths,
    - Geographic coverage,
    - Level of sharing (network and infrastructures)
    - Business assurance
- **Customer Visibility - High impact:**
    - Provisioning,
    - Charging and billing,

  - Terminals,
  - Monitoring and control,
  - Communication

- **Operational implications - Medium impact:**
  - Interworking,
  - EPC architecture and integration,
  - IMS,
  - IP addresses,
  - UICC/USIM and Milenage,
  - Network Planning & Optimization,
  - eNB parameterization,
  - Site characterization,
  - Backhaul.

- **Technical implications - Low impact:**
  - Synchronization,
  - Radius/AAA,
  - Lawful Interception,

- **Organizational implications:** Project Management

Note: the issues discussed are related with initial LTE implementation, assuming a 2G/3G network already deployed. Issues related with site acquisition & implementation or scalability derived from customer subscription and usages are not covered, as is the case for Backbone and international data acces..

1. Service scope

LTE/EPC network is an all IP network providing only one transport mode to all services. The list of services is considerable, and OPERATOR should define what are the services to be implemented on first rollout and when and how to complement this first list of services.

1.1 Mininum set of services

For a quick and simpler start, OPERATOR may consider for initial commercial offer a minimum set of services that are based solely on using LTE/EPC as a transport infrastructure (IMS and PCRF functionalities are optional controlling planes).

This minimum set of services includes Internet access, data streaming and OTT applications (if allowed by OPERATOR). The minimum set may include also any data service already provided by OPERATOR on the UMTS/GPRS network (mail service, etc.).

To be noted that this minimum set does not include voice, SMS and MMS, so LTE/EPC on this minimum set should be considered as an upgrade for data connection and not an alternate service for UMTS.

1.2 Optional services

A large list of services may be supported by LTE/EPC and could be introduced by OPERATOR at any time. Some will be a must on near time. They include:

- **Voice service with:**
    - Voice over LTE/EPC (VoLTE), implying an IMS architecture
    - or Circuit Switch Fall Back (CSFB)
    - SRVCC
- Identity management
- Messaging services
- Broadcast services (MBMS - Multimedia Broadcast Multicast Services)
- Location based services (LBS)
- Continuity services
- M2M services
- Gaming
- IPTV
- Real time audio, video, text
- Multimedia telephony supplementary services
- Multimedia messaging
- Presence
- Conferencing
- SMS over IP
- Early media
- Network announcements
- Online charging
- Inter-UE transfer
- Subscriber data management (Ut)

Every one of these services introduces (1) one or several layers of complexity on the network, (2) an array of important decisions to be made on the commercial aspects of the services, and (3) a whole new communication program with clients. It also implies some level of training/know how from OPERATOR to address all technical situations related with each of these services. Even if these services are introduced as outsourced projects, a deep focus from OPERATOR management and clear understanding of assumptions will be needed.

In order to minimize risks and speed LTE/EPC introduction, it is advisable to take out of the LTE/EPC launching any optional aspect that may increase difficulty and cause additional disturb on LTE/EPC implementation. LTE/EPC transport service is the simplest one to implement and the support to all other optional services.

1.3 Service characterization

- **QoS**
  - In order to take advantage of LTE capabilities, classes of service and their characteristics, to be used in the access network (QCI), have to be defined; some QCI values and characteristics have been standardized and should be adopted; this will guarantee expected QoE for services to be deployed
  - Classes of service and their characteristics, to be used in the core network (CSCP), and the respective mappings (QCI to DSCP), should be defined
  - LTE/EPC subscription's QoS profiles have to be defined; minimum are the parameters for the APN's default bearer (QCI, ARP and AMBR)
  - Policy control and charging requirements should be defined and, accordingly, a suitable PCC platform to enforce rules have to be installed
  - It is possible that minimum QoS be defined by regulator.
- **Handover**
  - Different possibilities exist for handover (see Interworking).
  - Handover should be minimized. The definition of the coverage area and frequencies used has a large impact on handover. Special care should be taken with (deep) indoor coverage if high bands are used (2.6GHz or 1.8GHz).
- **Throughput**
  - Maximum throughput per client an per service should be defined
  - Classes of throughput may be defined
  - Throughput stepping and triggers may be defined per service
  - On a uninterrupted coverage and on deep indoor, minimum throughputs should be specified
- **Interconnection**
  - Interconnection with other networks may be done over:
    - GRX or IPX carriers
    - I3 Forum
    - Dedicated links
    - Public internet
  - The choice within the options should be done based on (1) risk and then (2) cost:
    - Public internet should only be used to access public content.
    - Dedicated links may be used for national interconnections or peering.
    - All other interconnections should use GRX or IPX.

        - I3 Forum allows for usage of public internet implementing some recommendations for security. But because it does not implement multilateral interconnections is not yet an alternative to IPX or GRX
    - IPv6 is not supported yet on IPX on a multilateral basis, only bilateral.
    - Because of the importance of IP interconnection on LTE, issues do not end in SBC functionalities (session control, security, policy enforcement) but should also include provisioning, policy control and reporting.

- **Roaming**
    - Main decision areas:
        - GRX
        - Definition of LTE/EPC roaming partners
        - Choose an IPX provider
        - Check that the DCH/FCH/NRTRDE is LTE-compliant
        - Check that all roaming VAS are LTE-compliant
    - The interconnection between networks will be done with Diameter (IP protocol). This protocol may have different "flavors". Different networks are going to have different vendors, and even from the same vendors, there are going to be different versions of Diameter. So, getting all of them to talk to each other, including all of the different variants, is going to be a significant challenge
    - Is mandatory to have HSS and HLR integrated, as external networks can only "see" one Home Location entity in OPERATOR network.
    - Particular attention should be put on security risks with roaming (see Business Assurance)
    - Besides frequency band, OPERATOR must deal with LTE/EPC mode of operation: FDD and TDD modes are possible. So, OPERATOR must:
        - define what modes of operation are possible for outside roamers on OPERATOR's network,
        - and if OPERATOR mode of operation will be supported on roaming partners network.
    - Roaming agreements
        - Roaming agreements done before 2003 will need to be upgraded.
        - Roaming agreements done in 2003 or after, if already done on AA.12 and AA.13 (standard roaming agreement templates) are technology-neutral, so no updates are required for LTE.
        - There will be a specific LTE/EPC launch letter (like for 3G) to be send to roaming partners.
    - With TAP files also being in use for LTE impact should be minimal on existing invoicing and financial settlement processes. For example, financial clearing would work like it does today.
    - TAP records must be updated (TAP4 specification) to allow for IMS services and voice +SMS over LTE
    - LTE/EPC roaming allows for "local breakout" (besides Home Routed Traffic), meaning service will be provided with sole control of visited network. As so, roaming charging must rely on TAP accounting (for local breakout) and on PGW CDRs (when home network has the control).
    - Agreements and tests should be done on a bilateral case.
    - In near future some operators may setup a LTE/EPC signaling exchange (LSX) (KPN already provides one), which will act as a single interconnect, reducing complexity and allowing MNOs to connect to hundreds of other operators downstream.

- **Tethering**
    - This functionality is controlled by EPC. EPC supplier should provide OPERATOR with information on how to control this functionality and OPERATOR should decide how to use it (implications on service take-up and usage)

2. Assets to be deployed and responsability matrix

The following list includes the mandatory assets that should be procured by OPERATOR to implement a LTE/EPC minimum service (service scope).

The list also includes a proposal for the distribution of responsibilities to obtain and bring to service the specified assets:

Assets	Responsibilities	
	Action	Parties involved
Service license	OPERATOR	Telecommunications Authority
Radio license (Band, channels & bandwidth)	OPERATOR	Telecommunications Authority/ Telecom supplier
eNode Bs	Telecom supplier	
MME	Altice Labs	
HSS	Telecom supplier	
S-GW	**Altice Labs**	
PGW	**Altice Labs**	
PCRF	**Altice Labs**	
SBC	**Altice Labs**	
Terminals	OPERATOR	Several suppliers
IP addresses	OPERATOR	Regional Internet Registry
UICC/USIM	OPERATOR	SIM card suppliers
Milenage Algorithm	OPERATOR/Telecom supplier	
Upgrade Charging	**Altice Labs**	
Upgrade Billing	**Altice Labs**	
Upgrade provisioning	**Altice Labs**	
Upgrade OSS and probing	**Altice Labs**	
Upgrade sites	OPERATOR	Subcontractors

If OPERATOR wishes to include an IMS architecture, a complementary list of assets and responsibilities must be added:

Assets	Responsibilities	
	Action	Parties involved
DNS/ENUM	**Altice Labs**	
A-SBC covering A-BGF and P-CSCF functions	**Altice Labs**	
I-SBC covering I-BGF, I-BCF and IWF functions	**Altice Labs**	
LRF	**Altice Labs**	
MRFC and MRFP	**Altice Labs**	
I/S/E-CSCF	**Altice Labs**	
ATCF, ATGW and IMS-AGW	**Altice Labs**	

Depending on the services to be added, several Application Servers such as Multimedia Telephony (MMTEL), Voice over LTE (VoLTE), Centrex and Business Trunking Services, Service Centralization and Continuity (SCC AS) should be integrated. **Altice Labs** can supply all of them.

The following diagram depicts the high level functionalities within the LTE, EPC and IMS layers.

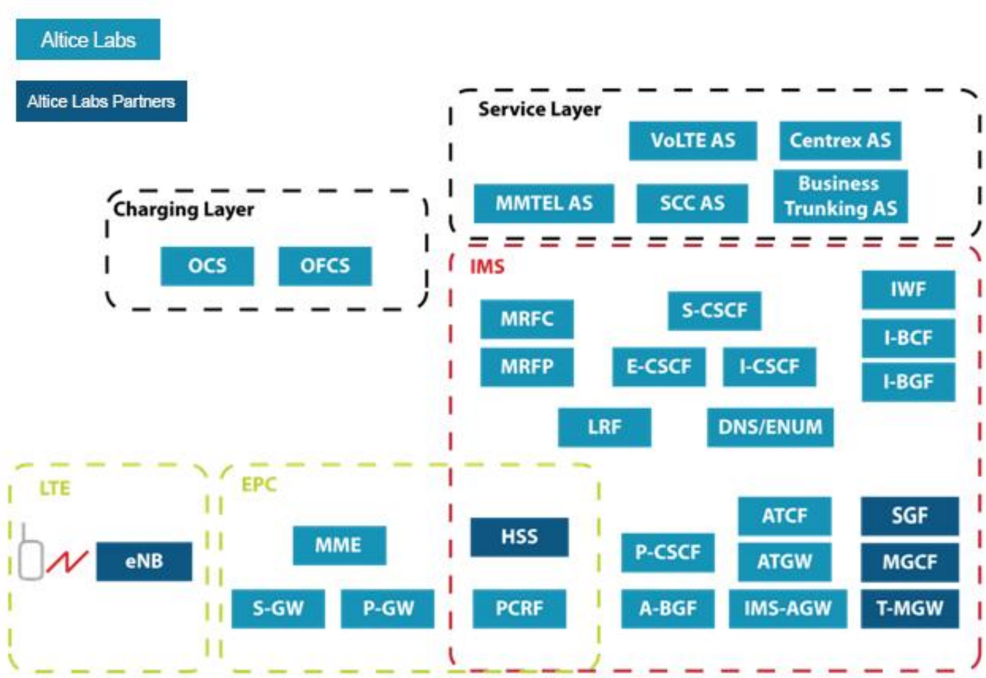


Figure 1: Architecture of LTE/EPC and IMS

Altice Labs (with partners) covers most of the functions depicted in the previous figure (shown in green).

3. Licenses, Frequencies and Bandwidth

It is assumed that OPERATOR already has a full telecom service license. To operate with LTE technology, being a radio access technology, OPERATOR must have access to radio frequency bands standardized for LTE usage. To be noted that standardization applies both to the frequency bands and the geographic region. Within frequency bands is also standardized the duplex mode of operation (FDD based on frequency division or TDD based on time division).

Below is a table showing all standardized bands for LTE (source 3GPP).

Table 1: Frequency bands assigned for use by LTE. (Source: 3GPP)

E UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit			Download (DL) operating band BS transmit UE receive			Duplex Mode
	FUL_low – FUL_high			FDL_low – FDL_high			
1	1920MHz	-	1980MHz	2110MHz	-	2170MHz	FDD
2	1850MHz	-	1910MHz	1930MHz	-	1990MHz	FDD
3	1710MHz	-	1785MHz	1805MHz	-	1880MHz	FDD
4	1710MHz	-	1755MHz	2110MHz	-	2155MHz	FDD
5	824MHz	-	849MHz	869MHz	-	894MHz	FDD
6	830MHz	-	840MHz	875MHz	-	885Mhz	FDD
7	2500MHz	-	257MHz	2620MHz	-	2690MHz	FDD
8	880MHz	-	915MHz	925MHz	-	960MHz	FDD
9	1749.9MHz	-	1784.9MHz	1844.9MHz	-	1879.9MHz	FDD
10	1710MHz	-	1770MHz	2110MHz	-	2170MHz	FDD
11	1427.9MHz	-	1447.9MHz	1475.9MHz	-	1495.9MHz	FDD
12	699MHz	-	716MHz	729MHz	-	746MHz	FDD
13	777MHz	-	787MHz	746MHz	-	756MHz	FDD
14	788MHz	-	798MHz	758MHz	-	768MHz	FDD
15	Reserved			Reserved			FDD
16	Reserved			Reserved			FDD
17	704MHz	-	716MHz	734MHz	-	746MHz	FDD
18	815MHz	-	830MHz	860MHz	-	875MHz	FDD
19	830MHz	-	845MHz	875MHz	-	890MHz	FDD
20	832MHz	-	862MHz	791MHz	-	821MHz	FDD
21	1447.9MHz	-	1462.9MHz	1495.9MHz	-	1510.9MHz	FDD
24	1626.5MHz	-	1660.5MHz	1525MHz	-	1559MHz	FDD
…							
33	1900MHz	-	1920MHz	1900MHz	-	1920MHz	TDD
34	2010MHz	-	2025MHz	2010MHz	-	2025MHz	TDD
35	1850MHz	-	1910MHz	1850MHz	-	1910MHz	TDD

36	1930MHz	-	1990MHz	1930MHz	-	1990MHz	TDD
37	1910MHz	-	1930MHz	1910MHz	-	1930MHz	TDD
38	2570MHz	-	2620MHz	2570MHz	-	2620MHz	TDD
39	1880MHz	-	1920MHz	1880MHz	-	1920MHz	TDD
40	2300MHz	-	2400MHz	2300MHz	-	2400MHz	TDD
41	2496MHz	-	2690MHz	2496MHz	-	2690MHz	TDD
42	3400MHz	-	3600MHz	3400MHz	-	3600MHz	TDD
43	3600MHz	-	3800MHz	3600MHz	-	3800MHz	TDD

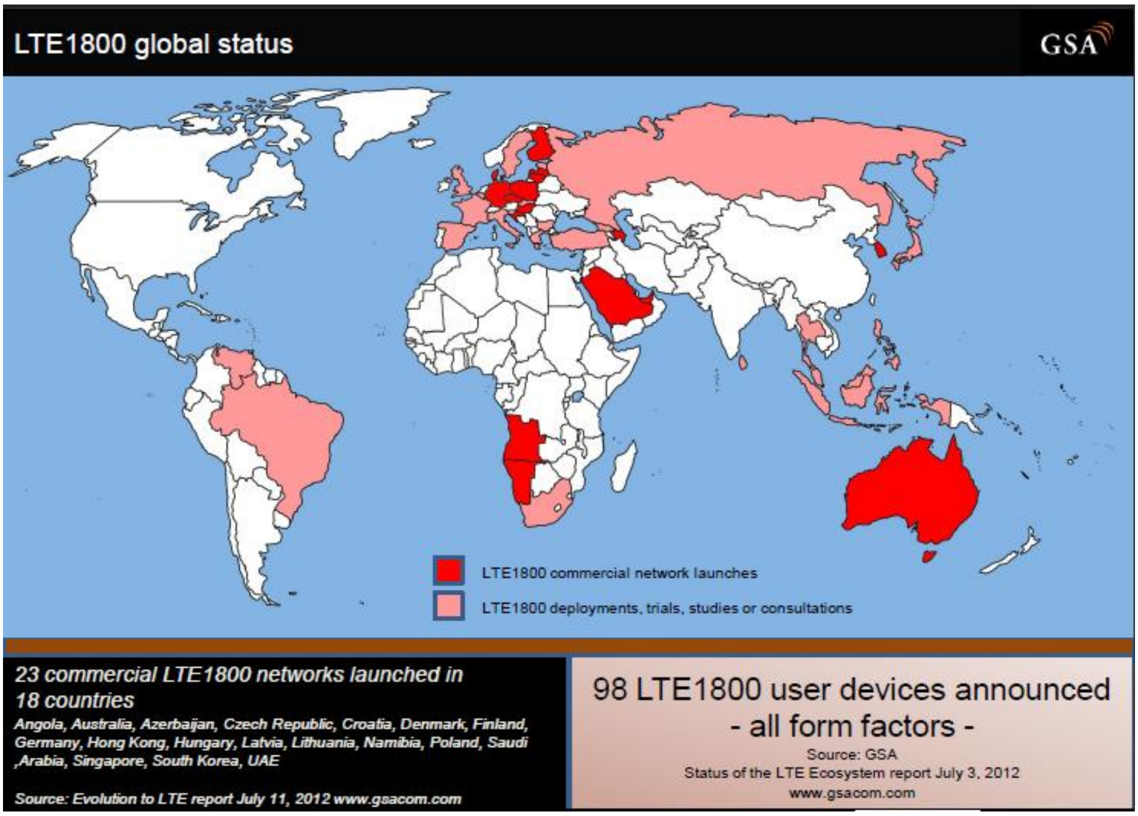
If OPERATOR already has a license to operate in these bands, the license must be a technology neutral radio license; otherwise a specific LTE license is needed. If OPERATOR wishes to use frequency bands not yet allowed by a license, it must apply for a license for the use of new frequencies. The license should be long term for a commercial service, or short term if for a pilot service.

The most used frequencies for LTE are in the 2.6GHz (band 7) and 800MHz (band 5). The 2.6GHz band is being used to add capacity in highly congested urban areas, and 800MHz are being used mainly for rural coverage.

OPERATOR may use, alternatively or in addition to the 2.6 GHz and 800MHz bands the refarming of their own allocated frequencies. For a GSM/UMTS OPERATOR, refarming of 1.8GHz frequencies (band 3) to LTE is becoming increasingly popular for urban and suburban coverage. It allows for:

- **CAPEX reduction**
  - reuse of spectrum
  - Reuse of sites and antennas

- **Short time to market** – band already available



Choose of the working bands have a large impact on the coverage area, terminal availability and roaming capabilities. If the intention is for urban coverage, 2.6GHz or, preferably, 1.8GHz should be used. 800MHz band is also a good choice for urban areas allowing for very good deep indoor experience, but with a much lower frequency reuse.

Terminal availability has a direct relationship with cost trough the scalability effect and also impact on roaming as terminals usually have a limited set of bands to work with.

Decision on the band(s) to implement LTE is one of the top decisions done by OPERATOR because global cost impact of being on the most used bands is very high!

Bandwidth allocations within the frequency bands have a direct impact on service throughput. Different bandwidths may be used on LTE, from 1.5MHz to 20MHz. Future LTE releases will allow for bandwidth concatenation, but this functionality must be paired with the terminals. To have a clear differentiation on experience from UMTS a minimum of 2x10MHz (FDD mode) is advisable. If possible allocate (at least) 20MHz contiguously.

4. Geographic scope (coverage)

A geographic scope should be defined by OPERATOR – defining the areas to be covered. This is the other top decision from OPERATOR as the coverage area has a direct and high impact on CAPEX. Best use of the assets may be the coverage of dense urban areas, if possible from existing sites. Co-siting with own GSM/UMTS cells may be a main objective for initial implementation.

For best quality of experience continuous coverage should be achieved.

As is been the case with 2G and 3G coverage, some minimum coverage may be mandated by the regulator (or accepted by OPERATOR) as a condition to license delivery.

5. Infrastructure sharing and network sharing

Investment for covering large areas is very high and is dependent on site, infrastructure and on equipment (eNB) costs. These costs are fixed, sunk and irreversible and as such they represent a high risk to the OPERATOR. OPERATOR should understand the full impact infrastructure and network sharing has on its figures, operation, and organization.

Infrastructure and network sharing allows:

- Reduced investment requirements
- Reduced operational costs
- Fast time to market
- New source of revenues
- Release of capital for strategic investments
- Shift focus to service innovation instead of network deployment
- Expand investments to less dense areas and meet universal service
- Optimize the use of resources
- Reduce negative environmental impact

Scope of infrastructure and network sharing has several dimensions and levels:

1. **Deep of sharing** – how infrastructure and equipment will be shared between operators
2. **Extent of sharing** – will it be only for LTE or should include UMTS and/or GSM
3. **Reach of sharing** – regarding coverage of rural areas or including also urban areas. May include national roaming
4. **Number of sharing parties** – may include one partner or all operators in a country
5. **Asset of sharing** – Who owns the assets
6. **O&M of sharing** – from each one responsible for its own O&M to outsourced O&M

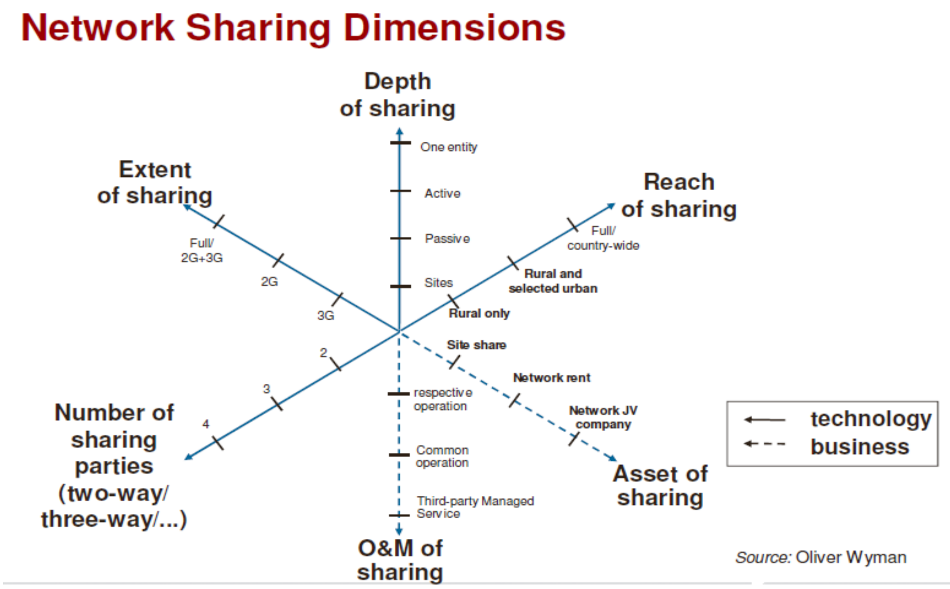


Figure 2: Network-sharing scoping model and dimensions (technology and business dimensions)

Option for infrastructure sharing is not difficult to implement or risky, but for a leading OPERATOR with a high developed coverage on UMTS/GSM the incentive is not so high.

According to AT Kearney, network sharing has proven to be one of the most effective ways of bringing down network costs, on both a relative and absolute scale.

Nevertheless this option must be carefully analyzed. Risks are also high and include:

- Network as a differentiator ceases to exist
- Regulatory aspects – who is responsible for what
- Compatibility of technologies if not on a greenfield solution
- Governance and management models need to be changed
- Equality of terms and conditions if operators are not on same level of network development
- Align technology, suppliers and road maps
- Independency of network operation

OPERATOR's decision on infrastructure and network sharing is a high deal decision and needs an in-depth assessment. The trend is on this direction but the road is rough and involves competitors, shareholders and regulators.

6. Business assurance (adapted from WeDo paper)

Telecommunication networks used to be very hard to attack, but the introduction of all-IP networks and new more powerful access technologies has opened up the previously closed Telco networks to the risks associated to the internet.

Being this domain a very specific one, specialized consulting on Business Assurance should be considered by OPERATOR.

Listed below are the main threats that will need to be addressed by OPERATOR within the framework of LTE/EPC implementation:

Telecoms threat landscape - The transition from the matured iPv4 connectivity in a core network and use as identifiers on a pool basis in networks will move to the new standard, IPv6, and this approach will only increase the level of risk.

Attack Areas in an "all IP" Network – LTE/EPC (all-IP) networks contain considerably fewer network elements than traditional 2G/3G networks, but while they are simpler the technical connections and interfaces increase, and this results in increased threat opportunities for criminal action. For example, Roaming in an IP world causes trust boundary issues between the carriers that are interworking and while in conventional Telco networks two carriers within their core networks check the user is able to access any services in a foreign roaming network, the foreign access network has to communicate to the home network for routing. Operators today use a backbone connection between each other, however, in an All-IP network, this will take place over the Internet where there is not the need for a roaming system and testing as before.

Wireless Threats - The radio network is changing in that more of the control and monitoring of transmission is part of the access point base station. This means they are open to more risk than witnessed in 2G/ 3G. Also the provision of IP connection for the access points means these are open and exposed to illegal connections or manipulation of traffic and setting back in the core network if there is not adequate security control and monitoring. In a similar way, the exploitation of items like home routers that form part of the 4G network, allow the user to some extent to manipulate the device for other issues such as man in the middle type attacks.

Threats from Users & Internet - The most critical interfaces in an all IP network are the interfaces between the differing traffic domains, for example, between the "user access planes", "signaling planes", "control domain", "operational domain", "provisioning", etc. Particular areas of weakness will be within the area of offsite connections from the core network either connected to an SBC or S(P)GW. Here there are issues on the supported secure signaling or media transfer and potential vulnerabilities in the higher level protocols. In particular IPv4 and IPv6, because they can directly access components in the operators' core network as an entry point to the IP layer which is visible to most users. It is also the easiest one to attack, due to the large number of ready available tools used for Internet hacking.

Revenue assurance - From a revenue assurance perspective there is an additional element in the End to End chain of both network mediation and a BSS mediation system when there are legacy access systems.

In addition to the billing event information the PCRF and network mediation device has a risk array of other information related to:

- Sessions and their use
- Quality parameters
- Top up and payment transaction for prepaid type services

- Authentication and access information dialogues from the HSS
- Session actions like CF, CC commands
- Roaming network location changes

7. Provisioning (HSS)

LTE/EPC clients must be provisioned on the HSS, but if they have handover possibilities on UMTS and GPRS networks they should also have a profile for UMTS and GSM/GPRS utilization.

New HSS and existing HLR can be 100% autonomous but there should be some external mechanism to guarantee that both are provisioned almost simultaneously and that information integrity is guarantee. One other option is to have HLR upgraded to support a HSS frontend (almost all current HLR supplier support a HSS collocated). This option can be more expensive if HSS is provided within a package with EPC, but often is a less error prone solution (It reduces external provisioning integration needs). As such, OPERATOR must decide if will be a new HSS autonomous from HLR or if will be an upgrade of existing HLR.

All LTE/EPC clients should be provisioned on the HSS, even if they also have a UMTS/GPRS profile. In case the HSS is autonomous from HLR that implies that the UMTS /GPRS network core elements (SGSN and GGSN) should be integrated with HSS (done by HSS supplier).

As the network may have now 2 Home Location Registries (HSS and HLR), the provisioning application operated on OPERATOR shops and agents (CARE from Altice Labs) should also interconnect with HSS and allow for correct provisioning. The application should allow for the correct provisioning either of a totally new client (LTE+UMTS+GPRS) or for an updated client (already UMTS+GPRS and now also LTE). This client should be automatically and simultaneously canceled at HLR and created at HSS.

Correct provisioning from CRM/Commercial Agents should be provided by Provision (CARE) supplier. This includes moving clients from and to HLR and HSS.

LTE/EPC supplier must provide an API on the HSS for (CARE) provisioning. This API should be forwarded to the Provision supplier (Altice Labs) so he can develop the adequate mediation.

8. Charging and Billing

Charging on LTE/EPC may be different from UMTS/GPRS:

If service is implemented over only one bearer per client (as in UMTS), all services will share the same bearer, thus sharing the QoS of that bearer and charging parameters (scenario 1).

If service is implemented over several bearers per client specific configurations should be supported and coordinated on EPC and on OCS (OFCS) and PCRF. Each service may have its own bearer with differentiated QoS and charging parameters (service differentiation) (scenario 2).

Charging is also different on the different 3GPP release decided by OPERATOR with supplier support. LTE/EPC is actually delivered with release 8 and release 9, being (actually) release 8 the most used.

As so, charging is dependent on how OPERATOR decides the set up of services and 3GPP release to be used.

In scenario 2 LTE/EPC allows for several types of charging, and these types may be used individually or in bundle. LTE/EPC charging may be based on: service, terminal, content, time, data volume, QoS and throughput.

The simplest form, as in scenario 1 and the one most operators apply, is the charging by data volume and throughput with only one bearer.

So, before proceeding with modifications on OCS(OFCS), PCRF and network parameterization, OPERATOR should decide on service implementation (bearers), portfolio and tariffs.

Service portfolio, tariffs and rating should be implemented on OCS(OFCS) and PCRF by supplier (Altice Labs).

Besides the changes on charging, OCS (OFCS) and PCRF must be interconnected with the new LTE/EPC core (PGW with standard interface Gx), and must collect CDRs from PGW. As LTE/EPC CDRs are different then UMTS CDRs, mediation should be provided:

If only OCS(OFCS) is receiving CDRs, then mediation may be done by OCS(OFCS)

If CDRs are used by other entities (revenue assurance, etc.) then mediation must be done by a separate application.

9. Terminals

LTE/EPC ecosystem includes now a long list of terminals (dongles, tablets, smartphones). They should be purchased bearing in mind the segments to provide service, but it is important to remember that all terminals should be paired with the LTE access frequencies defined for the network.

Important aspect for LTE terminals is the ability to roam to different bands and systems, especially during the first phases of roll out where coverage is limited. LTE terminals must support the legacy technologies and bands already used by OPERATOR.

LTE/EPC networks have two modes of operation:

- FDD – Frequency Division Duplexing
- TDD – Time Division Duplexing

Terminals may support both modes, even if OPERATOR network only uses one mode. Dual mode of operation will allow for roaming on any network (provided they use the same frequency bands).

10. Monitoring and control

LTE/EPC Supervision and performance gathering/reporting should be available on OPERATOR NOC. Supplier will deliver OMCs to perform these functions, but to have an integrated solution some mediation will be needed to integrate alarms and some Information Systems developments should be needed to integrate performance analysis (triggers) to have a service view (as opposed to the network view that can be autonomous).

Like on GSM or UMTS, besides gathering and analysis of LTE/EPC systems KPIs, autonomous probes to collect KPIs related with end to end Quality of Experience should be implemented. If OPERATOR already has probes for UMTS and GSM that allow upgrade to LTE, that should be the preferred approach.

11. Communication aspects

At this stage, and within a minimum service launch, LTE/EPC does not support the full range of services already supported in UMTS, namely voice, SMS and MMS. This situation should be clearly transmitted to LTE/EPC clients to manage client expectations

12. Interworking scope

Different levels of interworking exist:

1. LTE/EPC as an autonomous service (no interconnection)
2. LTE/EPC handover to and from own UMTS and GSM networks
3. LTE/EPC interworking with other national networks (LTE, UMTS or GSM/GPRS)
4. National and international roaming
5. LTE/EPC integration with WiFi (offload)
6. LTE/EPC handover between FDD and TDD versions
7. LTE/EPC integration with femtocells (HeNB)

The initial level of integration should be easy to obtain, to minimize impacts and provide a smooth and fast start of the service. If LTE/EPC is to be implemented on an area with UMTS or GSM coverage by the same supplier, OPERATOR should aim, at start, for level 2. On a subsequent implementation phase international roaming should be added (see Service Characterization – Roaming, page 7) to complement the service.

Depending on client usage on specific areas, integration with WiFi for offload will be a must on later implementation phases. For a seamless user experience a ANDSF server (Access Network Discovery and Selection Function) must be added to the EPC. This element allows mobile devices to know where, when and how to choose a non-3GPP access network. The implementation of the ANDSF implies the definition of prioritized rules that control which network should be used by the mobile terminal. The prioritized rules include the Inter-System Mobility Policies (ISMP) which defines when and where can the terminal connect to other networks, and the Inter-System Routing Policies (ISRP) which defines how to route applications' IP flows, when multiple interfaces are available at the same time.

An additional EPC element, the ePDG (Evolved Packet Data Gateway), adds the possibility of secure interworking between EPC and untrusted non-3GPP networks, like WLAN. This element terminates secure IP tunnels from the UE, managing traffic authentication on and authorization.

13. EPC architecture and integration (adapted from CISCO paper)

The deployment of LTE/EPC is another step in the evolution of mobile broadband networks. While the deployment of LTE radio access networks receives considerable attention, the multimedia core network (EPC) has emerged as a critical element in the delivery of next-generation mobile broadband services. As such, mobile operators are looking for solutions that can address today's requirements while positioning them for future technologies. The development of EPC, although often identified as an LTE-only mobility management core, was designed from inception with the mandate that it support all types of network access, and provide device and service mobility across all networks. The EPC has defined the connectivity, security, and expansion capabilities of the next-generation mobility core.

One of the key EPC considerations is the deployment architecture. The majority of UMTS core deployments use a centralized architecture where a centralized GGSN serves multiple SGSNs at distributed locations. EPC opens the door to revisit deployment architectures, including:

- **Centralized bearer/distributed control**: The traditional 3G architecture expanded to 4G where the PGW is located at a centralized location and the MME and SGW is distributed
- **Centralized control/distributed bearer**: A scenario where the PGW/SGW is distributed and the MME is located at a centralized location
- **Completely centralized**: An architecture where all the EPC functions are centralized
- **Completely distributed**: An architecture where all the EPC functions are distributed and generally deployed together

Another EPC consideration is integration (or collocation) of multiple core functions on a single platform. Options to consider are the integration of discreet 4G functions, and integration of 2G/3G, 4G, and/or non-3GPP core network functions to achieve capital and operational efficiencies along the upgrade path. For example, a single node acting as a collocated SGSN+MME and a node acting as a collocated GGSN+SGW+PGW can serve both the 2G/3G network and 4G network.

The following are some of the more common integration options:

- **Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN):** When EPC is deployed for 4G and requires mobility with an existing 2G/3G network, the EPC MME will interact with the SGSNs to perform mobility management. The signaling load between the MME and SGSN can be significant as the network grows. As separate nodes, both generate signaling traffic toward external nodes such as the Home Subscriber Server (HSS) and Mobile Switching Center (MSC). In an integrated SGSN/MME, signaling functions can be internalized, eliminating heavy signaling traffic between the two functions and external nodes. Additionally, performance and capacity utilization is substantially improved, reducing costs up to 30 percent over separate elements.
- **MME, SGSN, and Serving Gateway (SGW):** Additional performance and cost improvements are possible if the SGW is combined with the MME and SGSN. This could improve transaction performance by up to 80 percent over separate elements.
- **SGW and Packet Data Network Gateway (PGW):** The flexibility to split PGW functionality and collocate SGW and PGW functionality allows traffic to be offloaded from the network closer to the customer, eliminating backhaul costs for a large portion of traffic. In addition, this integration could lower CAPEX and OPEX as it takes fewer physical nodes to deploy and maintain, and the software and hardware utilization of the physical node will be better in many cases compared to separate nodes. Typical cost savings with this option range between 25 and 35 percent for a distributed deployment model, primarily from core network backhaul

savings. In the separate model, there is always some redundancy and leftover capacity in each node, not to mention the duplication of common functions.

As such, even if the first LTE/EPC roll out is done in overlay with UMTS, GSM or other mobile technologies, the tendency must be (sooner or later) to integrate all mobile cores within EPC.

One of the important aspects to analyze when deciding for core overlay or some sort of core integration is the capability of legacy 2G and 3G core network elements to interwork with EPC. This analyzes should be done in terms of protocols and also in terms of workload. A LTE/EPC network has a different way of dealing with sessions and signaling implying a heavy load on legacy systems. The load/performance of legacy systems needs to be addressed on launching phase but also on development phases taking in consideration future coverage, number of customers, services and usage patterns, and define what would the acceptable options be for a road map conducting to full core network integration. Initial architecture should be derived from this road map.

14. IMS

As referred previously, LTE/EPC is an IP-only technology meaning no CS domain is present. Thus, all services must be offered over the PS (IP) domain. This includes legacy services, as voice and SMS. In that context, IMS is not an option but is rather mandatory for the operators considering the introduction of LTE/EPC that do not want to stay just as pure connectivity providers.

IMS (IP Multimedia Sub-system) is standardized by 3GPP, and is already deployed in many operators around the world, both fixed and mobile, as a technology evolution to provide multimedia services over IP access and transport networks. In this scope, LTE/EPC+IMS is the way to go, together with IPv6.

IMS requires new controlling entities and service platforms, using different protocols with a special focus on SIP and Diameter. However, it may reuse services in the legacy service platforms and may also provide services to the legacy networks via adaptation entities. Complementary, it may share components with LTE/EPC, like HSS and PCRF.

A careful IMS dimensioning must be done, considering that for small deployment scenarios there are solutions providing complete IMS systems in single hardware platform, reducing cost and complexity.

Integration with legacy (GSM and UMTS), external (PSTN and other operators) and access networks, require adaptation entities at both control/signaling and media planes.

The deployment of an IMS platform in addition to the LTE/EPC access network, will enable the deployment of several services, like VoLTE, RCS, video streaming or ip-Centrex.

Complementary aspects, like service centralization and continuity need to be evaluated and be part of the LTE/EPC introduction strategy. That will depend on the evolution roadmap of the existing equipment, like MSCs, as well as on the geographical coverage of the LTE/EPC network. That will require the deployment of special entities like SCC-AS.

15. IP addresses

LTE/EPC supports IPv4 and IPv6, via the introduction of dual-stack PDP contexts.

On the radio access network, if both are allowed, it is up to the application/terminal to decide which protocol to use. In the case of IPv4 the address may be private.

On interconnection, with GRX or IPX supplier, OPERATOR needs to decide how many simultaneous sessions it should support both on IPv4 and IPv6, and dimension, obtain and allocate IP public addresses accordingly. This means that OPERATOR has to manage its own pool of public IPv4 addresses or obtain new addresses from Regional Internet Registry taking into consideration that the regional pool is almost empty (in some regions is already empty).

If OPERATOR wishes to implement IPv6 along with IPv4 on LTE/EPC (dual-stack scenario), IPv6 addresses should be obtained from the Regional Internet Registry (Afrinic in Africa), and an impact analysis must be done on existing network, service platforms and OSS/BSS systems, along with the definition of OPERATOR introduction strategy for IPv6.

The adoption of IPv6 may be done at different degrees or phases:

1. only in the access to the services provided to OPERATOR and external clients (access networks and Internet)
    a. most likely it will require adaptation nodes to provide an IPv6 frontend to services that will stay running on IPv4
    b. some platforms that need to handle, in some way, the IPv6 addresses, will require an update
2. service platforms will, in the possible extend and according to their architecture, migrate to IPv6; internal networks, management and operation platforms will stay running in IPv4; as previously, a careful analysis of the IPv6 impact must be done, even for the components that will not start communicating over IPv6
3. all OPERATOR networks, service platforms, OSS and BSS systems will communicate using the IPv6 protocol.

In any case, a dual-stack operation (IPv4 and IPv6 running in parallel) should be expected for a long period, while the overall Internet, service providers and terminal equipments do not all migrate to IPv6.

Besides IP connectivity supporting elements (routers, firewalls, access equipment, AAA, DHCP, DNS, etc), the introduction of IPv6 has impacts on OSS and BSS platforms. For instance, if IPv6 connectivity is going to be given, than CDR generated by network elements must contain IPv6 data. Thus, the introduction of IPv6 must involve all the company, evaluating all the aspects and drawing a consistent strategy.

Both IPv4 and IPv6 addresses may be distributed to LTE/EPC terminals, either autonomously by the network itself or through AAA. The second option allows for static IP attribution to clients (used with corporate services). In a dual-stack operation, the assignment of IP addresses may be done in several ways, and to different clients, based, for instance, on their value, profile or subscribed services:

(i) IPv6-only (global addresses)
(ii) IPv4-only, public
(iii) IPv4-only, private
(iv) IPv6 (global)+IPv4 (public)
(v) IPv6 (global)+IPv4 private)

Together with the selection of the strategy to introduce IPv6 and its coexistence with IPv4, with public or private addressing, the adoption of transition mechanisms (tunneling and/or translation) must also be considered in order to avoid loss of connectivity between OPERATOR clients, OPERATOR service platforms and the Internet, independently of the adopted protocol version and type.

At the same time, OPERATOR may take the opportunity to evaluate the internal usage of IPv4 addressing optimizing it. Possibly, there are some internal networks where public addressing is being used and a private one may well be adopted.

Even if the basic operating principles are the same as for IPv4, the introduction of IPv6 will require OPERATOR staff training. New addressing schema, new addressing space assignment rules, new packet structure, no ARP mechanisms and no broadcast, introduction of transition mechanisms between IPv6 and IPv4, are just a few aspects that will require the acquisition of solid knowledge and experience in order to be able to design, understand and evaluate network operation.

16. UICC/USIM and Milenage (COMP128-4)

LTE/EPC terminals should work with UICC SIM cards and with a USIM application inside. These UICC cards and USIM application are compatible with UMTS/GPRS operation.

OPERATOR should define a USIM electrical profile for its clients and obtain a batch of SIM cards for LTE/EPC terminal operation from a SIM card supplier. The process includes, besides the profile definition, the production of the test cards, the test of those cards with OPERATOR LTE/EPC network, the production of the normal cards and its distribution. This process may take several weeks.

It is advisable for OPERATOR to use SIM Profile Markup Language (SIMpml) that provides a standardized description of SIM profiles, allowing for faster creation and validation of profiles and its reusability (see SIM Alliance).

The USIM application needs a Milenage authentication procedure.

OPERATOR should obtain from the network supplier the Milenage Algorithm and define its customization. This customization is not mandatory, but is advisable to have it, corresponding to one level up on the security of the SIM card. The customization is the definition of a 128 bit field called OP on the algorithm. This OP value should be kept secret to OPERATOR.

It is up to the network supplier to implement Milenage on the HSS that should work with UICC/USIM on the terminal.

The UICC/USIM may also be used with UMTS terminals.

17. Network Planning, optimization and eNB parameterization

Specific tools and know how are needed to plan and implement a LTE/EPC radio network.

OPERATOR may follow one of two options for network planning, optimization and parameterization:

- Done by eNB supplier
- Done by 3rd party

First one is simpler but has as drawback that network may be over engineered (extra CAPEX) and OPERATOR will not have visibility over how network is implemented. Network will be accepted (and operated) based on service specification and not on network specification.

Second is transparent, has a check on supplier delivery and performance, but has as drawbacks that procedures are more complicated and will take more time to implement. Network may be accepted based on macro template for eNBs that should include key network and service parameters (validated by network planning 3rd party), and optimization done by network planning 3rd party.

Without the help of a 3rd party, all key network and service parameters should be defined by OPERATOR, requiring specific know how on LTE/EPC technology, or defined by supplier, being OPERATOR totally dependent on the knowhow of the supplier.

18. Site characterization

LTE/EPC should use as possible existing sites. Inclusion of LTE equipment on an existing site (own or shared) implies the evaluation of all site ecosystem. This evaluation is impacted and has impact on the type of eNBs to be used: distributed type with radio unit separated from baseband unit, or radio + baseband unit on the same shelf.

Scope management for existing sites may include some of the following issues:

- Legal clauses, existing procedures and/or technical limits on shared sites,
- Legal clauses on rented sites,
- Resources to evaluate/update
  - Power supply (including grid power, batteries and generators)
  - Air conditioning,
  - Shelter or cabinet space
  - Weight on the tower/mast caused by antennas, cables and outdoor equipment
  - Resistance to torsion due to wind
  - Grounding
- Antenna issues to consider:
  - Choice/reuse of antennas. Refarming of frequencies may allow for reuse of existing antennas.
  - Antenna altitude. Coverage is improved with clearance from surrounding obstacles. From network planning phase some tradeoffs must be made related with antenna altitude, sector angle, emitted power and coverage.
  - Interference/noise impact on existing services (antenna decoupling).
  - Number of antennas. LTE/EPC uses a minimum of 2 antennas per cell but may evolve to use 4 or 8 antennas per cell (MIMO technology).
- Resources Site layout (where to locate eNB's). Baseband Units of eNB's (BBUs) must be located indoor, but if distributed eNB's are used, they may be installed/aggregated on a different site then the Remote Radio Units (RRUs) will be installed. For RRUs, besides indoor versus outdoor decision, outdoor location have several different options. Site layout has impact on tower/mast, emitted power, space availability, cabling, air conditioning, backhaul and power supply.

19. Backhaul

LTE/EPC has a strong impact on backhaul because of the need to transport huge amounts of data from eNBs. Use of Fiber technologies is advisable with FE or GE interfaces. Fiber backhaul system architecture may be ring or star shaped on the aggregation part, with MPLS technology, and tree shaped with xGPON systems on the access part (FTTx). This last option allows for a seamless integration of backhaul in the access network of an operator with New Generation Access (NGA).

Microwave links are also possible but should also provide FE or GE interfaces and over 100Mb/s capacity. Both should include Ethernet switching functionality to directly aggregate eNB links along the way. In some cases ring protection should be needed.

Main decisions to be taken on backhaul are how and when transport integration (LTE + UMTS + GSM) should happen. These decisions should be taken with objective of full transport network optimization and not only LTE deployment.

If is envisaged the use of distributed eNB's with BBUs and RRUs in different sites, fiber backhaul must integrate these needs. As distributed eNBs use CPRI protocol, backhaul must be done with separated fibers for CPRI and Ethernet or SDH.

20. Synchronization

The eNBs must be synchronized with EPC. The LTE/EPC synchronization, besides frequency synch, must include phase synch. Only E1s or PTP (Precision Timing Protocol) synchronization can deliver phase synch. GPS or Synch Ethernet only deliver frequency synch.

For the minimum service scope OPERATOR may use the same synchronization method used with UMTS (GPS, E1, PTP or Synch Ethernet). Internet access and streaming on LTE/EPC tolerate a GPS synch.

Nevertheless, OPERATOR network is evolving to an all IP network, and E1s will not be an option in the future. It is advisable for OPERATOR to start introducing PTP synchronization (IEEE 1588v2). Because this standard also has some “flavors” is important that either OPERATOR preliminary tests synchronization server with eNBs (if from different suppliers) or uses a synchronization server already certified to be used with eNB.

21. Radius/AAA

The existing Radius /AAA must be integrated with EPC. This task should be done by EPC supplier and Radius/AAA supplier. Detail design must be carefully executed since there's a lot of different approaches to the Authentication, Authorization and Accounting. The set of roles for AAA is usually different from operator to operator and a match between EPC and AAA must be achieved.

22. Lawful interception

It is necessary to evaluate the LI interfaces. LTE/EPC interfaces for LI are the same as for UMTS, but should be addressed with the legal entity if OPERATOR should integrate all information gathered on the LI interfaces (LTE/EPC and UMTS) and provide only one aggregated output or deliver one interface per technology. For the first scenario OPERATOR will need to provide mediation to the legal entity to avoid changes on legal entity side.

23. Supplier services

With the rollout of a new technology, particularly with one as LTE/EPC with so many variables, there is a lot of parameterization that is on the responsibility of the OPERATOR.

To address the definition of all the needed parameters, OPERATOR must have (internally or trough consulting services) specific expertise on LTE/EPC (technology and services), or OPERATOR may work only with (RAN and EPC) suppliers support. OPERATOR should decide on the adequate balance (either on technology or on service aspects) in order of setting up know how and managing dependence on supplier.

Nevertheless, an adequate framework of (consulting) services must be agreed from beginning of rollout with suppliers or external consultants.

24. Project management

Introduction of a new technology is always a difficult phase for an OPERATOR. OPERATOR aims for efficacy in day to day operations, and a new technology introduces a shift of focus, a drain on resources and most of the times a gap on know how either on management and on engineering.

Commercial introduction of LTE/EPC, as shown in this document, is time limited task and implies a need to address a long list of issues, with impact all over the company, in a global and organized way. It is also a high investment project with budget and time constraints and lots of risks associated with it.

Experience shows that a Project Management and the corresponding Governance and staffing are a must that needs to be addressed by OPERATOR. In addressing Project Management the main issues to be taken in consideration are:

- Scope
- Resources, Time and Budget
- Governance (powers and policies)
- Organization
- Allocation of responsibilities
- Staffing
- Know how
- Deliverables

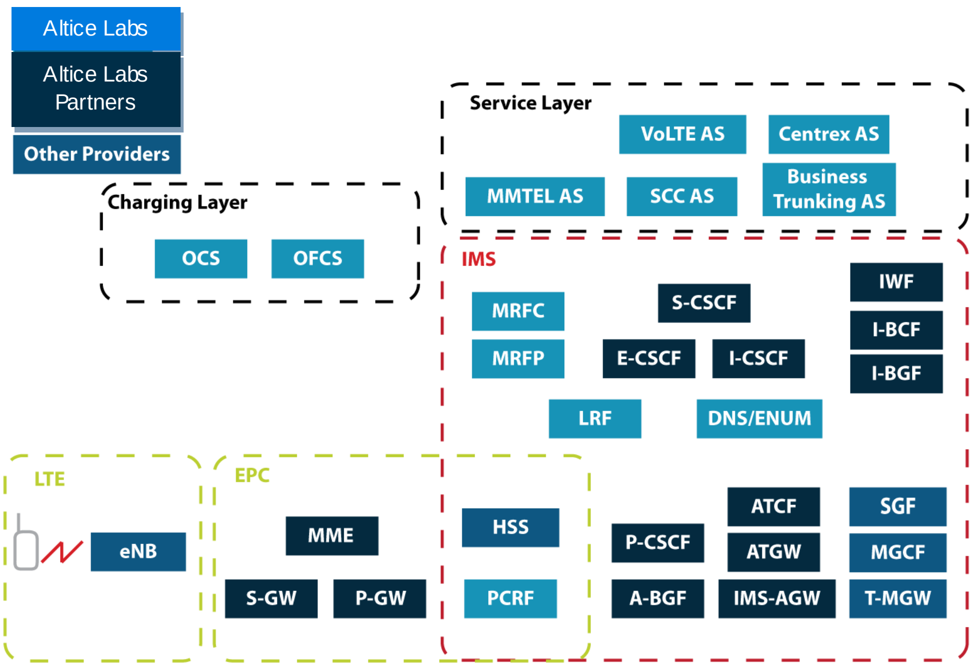
Depending on size and risks of the project and know how detained by OPERATOR, important decisions concerning Project Management should be made, including:

- Project responsibilities by OPERATOR
- Level of outsourcing, organization of outsourcers and allocation of responsibilities to outsourcers.

25. Altice Labs

Altice Labs has a broad expertise on LTE/EPC ecosystem, and supplies, installs and integrates all EPC network and platforms, BSS/OSS, QoS monitoring and backhaul.

LTE/EPC and IMS products offered by Altice Labs are depicted in the following picture:



List of LTE/EPC and IMS products offered by Altice Labs:

- EPC (MME, S-GW and P-GW)
- PCRF
- Online (OCS) and Off-Line Charging Systems (OFCS) Backhaul
- OSS
- QoS monitoring
- DNS/ENUM
- A-SBC covering A-BGF and P-CSCF functionalities
- I-SBC covering I-BGF, I-BCF and IWF functionalities
- LRF
- MRFC and MRFP
- I/S/E-CSCF
- ATCF, ATGW and IMS-AGW
- Several Application Servers addressing features such as Multimedia Telephony (MMTEL), Voice over LTE (VoLTE), Centrex and Business Trunking Services, Service Centralization and Continuity (SCC AS) – **Altice Labs**.

With product development, installation and integration, Altice Labs has developed and can also offer a complete list of services that may go with equipments or be supplied separately like:

LTE/EPC services offered by Altice Labs:

- Technical Consulting
- Project management
- Mediation and systems integration including IT
- Network and services acceptance
- Technical training and coaching

ACME Packet, CISCO and WeDo are ALTICE LABS partners.

26. List of Acronyms

2G	Second Generation mobile network - GSM
3G	Third Generation mobile network - UMTS
3GPP	Third Generation Partnership Project
AAA	Authorization, Authentication and Access
AA12	Template from GSMA for roaming
AA13	Template from GSMA for roaming
AMBR	Aggregated Maximum Bit Rate
API	Application Programming Interface
ARP	Allocation and Retention Policy
BSS	Business Support System
CAPEX	CAPital EXpenditure
CDR	Call Detail Record
CRM	Customer Relationship Management
CS	Circuit Switch
CSCP	Call Session Control Platform
CSFB	Circuit Switch Fall Back
DCH	Data Channel
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DSCP	Differentiated Services Code Point
E1	European Basic multiplexing rate
e Node B	Evolved Node B
EPC	Evolved Packet Core
FCH	Frame Control Header
FDD	Frequency Division Duplex
FE	Fast Ethernet
GE	Gigabit Ethernet
GPRS	Generic Packet Radio System
GPS	Global Position System
GRX	GPRS eXchange
GSM	Global System Mobile
GSMA	GSM Association
HeNB	Femtocell – Home Extended Node B
HLR	Home Location Registry
HSS	Home Subscriber Server
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPTV	IP Television

IPv4	IP version 4
IPv6	IP version 6
IPX	Internet Protocol eXchange
LBS	Location Based Services
LI	Lawful Interception
LTE	Long Term Evolution
LSX	LTE/EPC Signaling eXchange
MBMS	Multimedia Broadcast Multicast Service
MME	Mobile Management Entity
MNO	Mobile Network Operator
MMS	MultiMedia Message Service
MSC	Mobile Switching Center
NOC	Network Operating Centre
NRTRDE	Near Real Time Roaming Data Exchange
OCS	On line Charging System
OFCS	Off line Charging System
OMC	Operation and Maintenance Centre
OP	Milenage Parameter
OSS	Operational Support Systems
OTT	Over The Top
PCRF	Policy Control and Resource Functions
PDP	Packet Data Protocol
PGW	Packet data network Gateway
PSTN	Public Switched Telephone Network
PTP	Precision Timing Protocol
QCI	Quality of Service Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
RCS	Rich Communication Suite
SBC	Session Border Control
S-GW	Server Gateway
SIM	Subscriber Identity Module
SMS	Short Message Service
SRVCC	Single Radio Voice Call Continuity
TAP	Transferred Account Procedure
TDD	Time Division Duplex
UICC	UMTS Integrated Circuit Card
UMTS	Universal Mobile Telecommunications System
USIM	Universal Subscriber Identity Module
VAS	Value Added Services

VoLTE	Voice over LTE
WiFi	IEEE 802.11 Protocol

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