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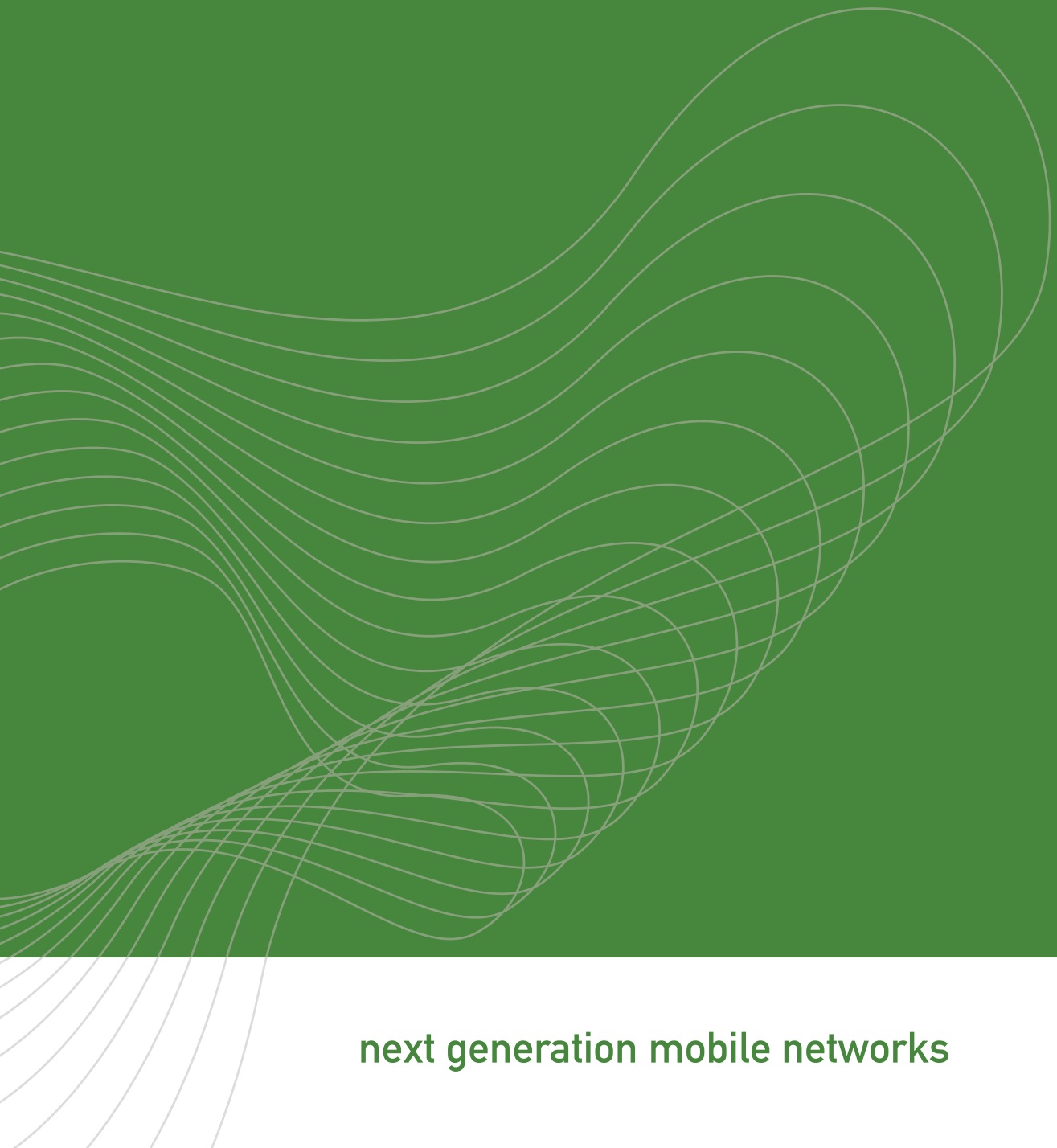
A White Paper by the NGMN Alliance

# NGMN Technical Achievements 2007 – 2010



next generation mobile networks

# NGMN Technical Achievements 2007 – 2010

## A White Paper by the NGMN Alliance

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| WORKING GROUP | TWG SC |
| PROJECT | - |
| EDITOR- IN- CHARGE | MOHAMMAD SHAHBAZ |
| EDITING TEAM | JOHN BOGGIS, ANDREA BULDORINI, FRANCK EMMERICH, LOU FEIFEI, WALTER GRETHE, JINRI HUANG, LIU LEI, ATSUSHI MINOKUCHI, CHRIS PUDNEY, NICK SAMPSON, PETER STEVENS |
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## Contents

# 1 EXECUTIVE SUMMARY

This document provides an overview on a selection of NGMN Alliance technical activities, which have been carried out in Technical Working Groups and Trial Working Groups from 2007 to 2010. It describes the major achievements of the activities with a reference to the detailed reports respectively.

The work of all workgroup-, project-, stream leads and project members from both operators and vendors to achieve the significant results is highly appreciated. The NGMN Alliance would like to take the opportunity to thank all contributors for their valuable input, enduring commitment and their continuous support.

The founding members of NGMN Alliance published the operator view on next generation of mobile networks beyond HSPA and EVDO in the NGMN White Paper version 3.0, 2006, and agreed on the following major milestones [1]:

| | |
|---|---|
| End of 2008: | Standards completed |
| In 2009: | Systems available for operator trials |
| In 2010: | Commercial service possible on a country and operator specific basis |

Almost all activities in Technical Working Group (TWG) and Trial Working Group were focussed on successful completion of standards and availability of systems for operator trials.

The TWG started with the identification of gaps between the NGMN recommendations and Standards, and initiated several technical activities to consolidate the operator views and to support the industry by closing these gaps. Most of these activities needed a deeper dive into the technical areas touched in the NGMN White Paper 3.0 respectively.

This document should provide an easy access to technical achievements on device aspects, network aspects, technology evaluation, trials, testing, and measurement aspects.

The chapter on **device aspects** introduces the detailed NGMN radio access terminal requirements. The initial terminal device definition activity was initiated to reduce the requirements to a minimal set for the start of next generation mobile networks. The TDD/FDD terminal chipset solutions, device certification, agreements regarding Voice and SMS in LTE to ensure roaming from day one, and executive workshops on devices served to support, guide and drive the industry.

The chapter on **network aspects** deals with activities around multi-vendor RAN, support of Broadcast and Multicast, backhaul, security, self-optimising networks, operation, administration and maintenance, database convergence, and deployment recommendations.

The chapter on **technology evaluation** describes the NGMN activity in 2007-2008 to verify the compliance of the technologies LTE and WiMAX with NGMN recommendations. We will refer to the simulation methodology behind the evaluation, the evaluation study of LTE and IEEE 802.16e, and the conclusion on the technology evaluation in 2008. To introduce more transparency regarding peak data rates vs. perceived data rates by customers, we started mid 2009 an activity on definition, a metric to determine typical user data rates for HSPA, HSPA+, and LTE technologies, we report in the last section of this chapter.

The **Trials, Testing, Measurement Aspects** chapter in this document describes the technical achievements in the area of **trials, testing and measurement aspects** to efficiently prepare for commercial launch.

In the final chapter **Conclusions** a summary of key achievements made within the technical and trial working group can be found.
In the **Appendix**, for information, several listings should serve as useful references for the readers.

# 2 DEVICE ASPECTS

One of the most critical factors behind the success of next generation mobile networks will be the early availability of low cost, robust, and versatile reconfigurable devices with low power consumption [1]. To ensure NGMN milestones and timescale, three projects on terminals were initiated, namely radio access terminal requirements, initial terminal device definition and terminal certification. In 2008 a series of workshops with C-level attendants with the title Executive Workshop on Devices was initiated. These workshops were held to progress and monitor the development for devices and their capabilities and features in order to have a uniformed approach to the upcoming next generation mobile network launches.

## 2.1 Radio Access Terminal Requirements

The idea behind this project (aka Project 8 – Terminal Aspects) was to develop and agree on NGMN radio access terminal requirements between NGMN members, Partners and SDOs and related industry in general [2]. The key criteria for the development of the requirements were a) timely introduction of the next generation of mobile networks, b) commercial deployment by 2010, c) terminal in commercial volumes, d) compliance with key NGMN requirements (e.g. NGMN White Paper V3.0, [1]), and e) effective services enabling..

Besides aligning the main NGMN requirements to Terminal, i.e services classes enabling, multi-mode operation, transmission rates, mobility, latency, authentication, security, roaming, etc., the following areas were covered: radio access and technology, terminal complexity, software platform, spectrum usage, user equipment classes, and Inter-working making possible intra/inter system handovers (see Figure 1).

This activity started in April 2007 to address above objectives and the work was concluded in May 2008.

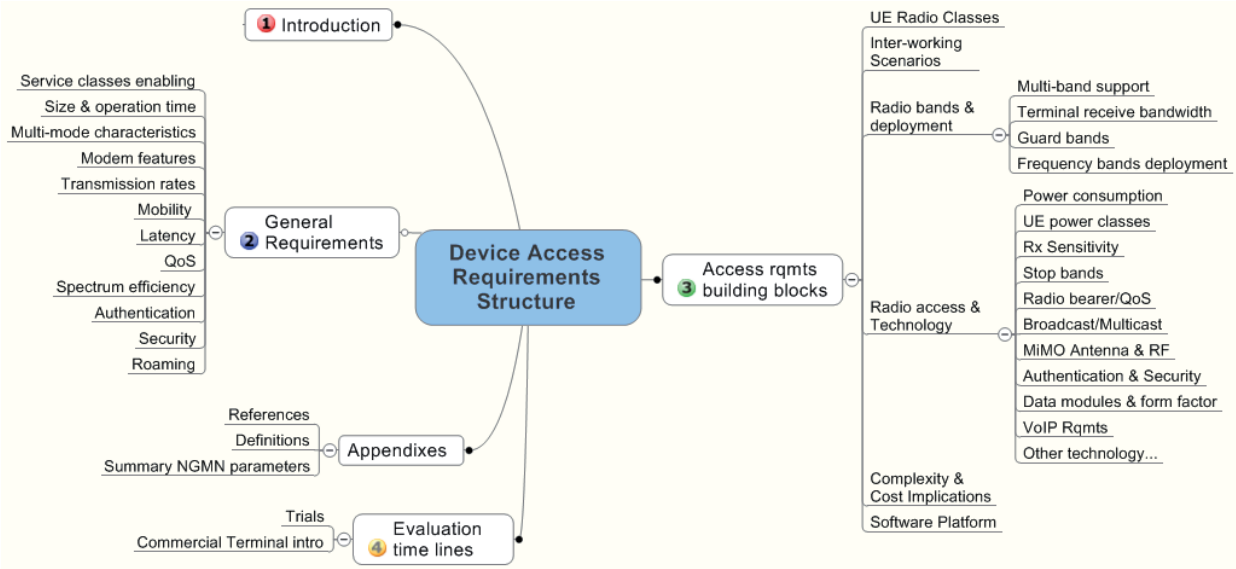



**Figure 1: Structure and categories of NGMN radio access terminal requirements**

The 180 requirements in the final deliverable of this activity take into account the first consultative iterations with leading chipset suppliers and Terminal manufactures, as well as the progress made in the standard bodies such as 3GPP.

For commercial product, NGMN Project 8 requires implementation of the following:

| No | Requirement | Readiness@ NGMN Intro |
|---|---|---|
| R54 | in a first step: a quad band GSM, a tri band UMTS ( 2 high and 1 low), a tri band LTE (2 high and 1 low) | 2010 |
| R55 | in a second step: a quad band GSM, a quad band UMTS (3 high and 1 low), a quad band LTE (3 high & 1 low),and a quad band LTE with (2 low and 2 high frequencies) | 2010+1 |

- High bands are defined as frequency bands over 1GHz
- Low bands are defined as frequency bands below 1GHz.

The result of this work is publicly available on NGMN portal, "NGMN Radio Access Terminal Requirements" [2].

The outcome of this activity was two folds:

1. to ensure the timely availability of next generation terminals, regular consultative discussions with chipset suppliers and Terminal manufactures is a must. Therefore, the Executive Device Workshop on devices as a new platform in NGMN was created. The Executive Device Workshop has served successfully to keep up on-going discussion between operators and chipset and terminal vendors and remove issues timely.
2. to define and agree on the initial terminal and device requirements based on the 180 requirements' list.

## 2.2 Initial Terminal Device Definition

The project on "Initial Terminal Device Definition" (P-ITDD) was initiated to provide the generic definition of an initial release next generation terminal/device, considering a macro view of the marketplace needs on a global and/or regional basis balanced against the practical reality of terminal/device implementation. The project will focus on the initial market time frame and includes radio interface technology combinations, band combinations, capabilities and feature sets and services, use cases, target market, form factor, roaming and fall-back, regional perspectives, and future roadmap. The intent was to provide a specific, yet generic, description of an initial release device [3].

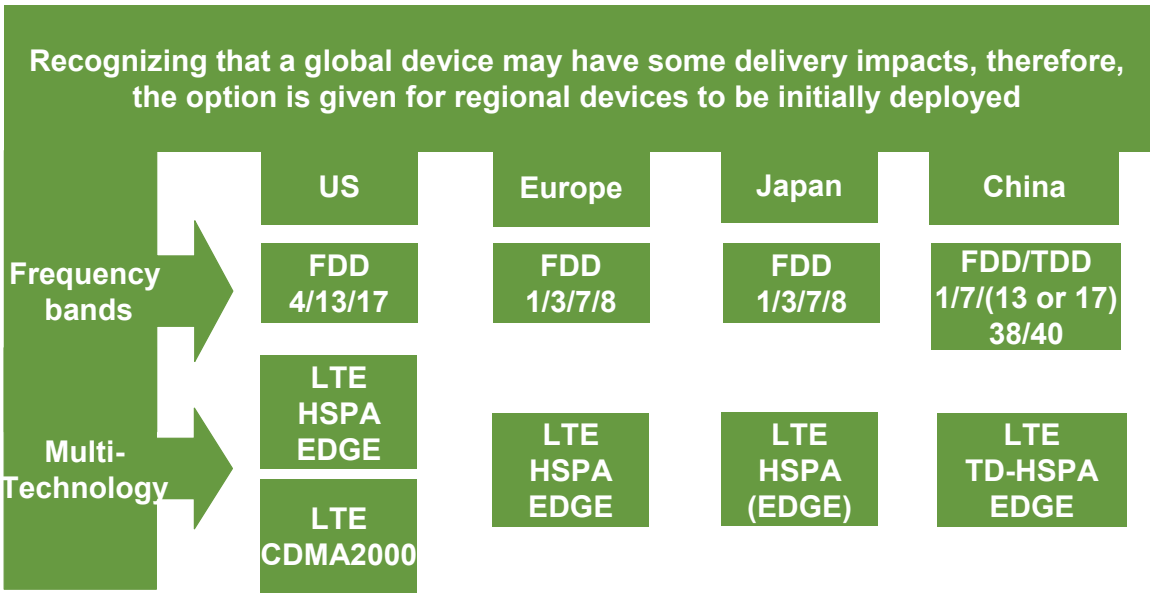
The NGMN project P-ITDD has examined the results from Project "NGMN Radio Access Terminal Requirements" [2] (aka Project 8) and Project "Initial Deployment Targets [6] (aka Project 10), taking into account the overall scope and goals of NGMN.

In April 2008 this activity started to address the above objectives and the work was concluded in January 2009. The final version which added Band 17 was approved by NGMN board in May 2009.

The results of this project define a Data-Only device for delivery in 2010. Frequency bands and usage context were of primary concern during the course of this project; it was realized that too many requirements could possibly delay production of devices, while a broad definition would not be sufficient to provide information to the industry for the actual production of such devices.

During the course of this project, it was decided that two basic types of initial Data-Only devices should be defined. A Global Roaming Target Device, and a Regionally Focused Device. Furthermore, the Regionally Focused Device is according to particular regions. In the case of this project, the regions are Asia (China), Asia (Japan), Asia

(Korea), Europe, and North America. NGMN believes this gives clear direction to the industry, allowing suppliers to focus on the Global Roaming Target Device, but recognizing that this Global device may have some delivery impacts, therefore, the option is given for regional devices to be initially deployed.




On legacy technologies, multi band support is required: EDGE(4 bands); HSPA/CDMA2000(2 to 4 bands)

**Figure 2: Preferred Regionally Focused Device recommended by P-ITDD**

The preferred Global roaming device should be a dual mode (FDD/TDD) device and support the following technologies on the prioritized bands:

- LTE FDD mode support for Europe, Japan, Korea, US, Canada
- LTE TDD mode support for China

The preferred Global roaming device should also support all or a subset of the following technologies on the prioritized bands:

- EDGE mode for international roaming for countries without nation-wide 3G/LTE coverage
- UMTS/HSPA mode for roaming to Europe, Japan, US, Canada and Korea with high data rates in countries where nation-wide LTE coverage is not available in the time frame of this deliverable
- HRPD/1xRTT mode for roaming to US, Korea with high data rates in countries where nation -wide LTE coverage is not available in the time frame of this deliverable

The preferred Regionally Focused Device recommended by P-ITDD (see Figure 2):

- The recommended ITDD LTE device configuration for Europe and Japan supports the bands 1/3/7/8. The support of Band 7 with 20 MHz bandwidth is important to show LTE peak data rates.
- The recommended ITDD LTE device configuration for USA is the support of Bands 4/13/17.
- The recommended ITDD LTE device configuration for China supports the bands 1/7/(13 or 17) (FDD) and 38/40 (TDD).

The result of this work is publicly available on NGMN portal, “NGMN Initial Terminal Device Definition” [3].

The requirements on initial terminal device definition represent the current status of operator consolidation work. The adaptation of on-going industry development is needed (e.g. “Digital Dividend” in Europe).

**Table 1: Excerpt of E-UTRA operating Bands [TS 36.104]**

| E-UTRA Operating Band | Uplink (UL) operating band BS receive UE transmit | Downlink (DL) operating band BS transmit UE receive | Duplex Mode |
|---|---|---|---|
| | $F_{UL\_low}$ – $F_{UL\_high}$ | $F_{DL\_low}$ – $F_{DL\_high}$ | |
| 1 | 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |
| 3 | 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |
| 4 | 1710 MHz – 1755 MHz | 2110 MHz – 2155 MHz | FDD |
| 7 | 2500 MHz – 2570 MHz | 2620 MHz – 2690 MHz | FDD |
| 8 | 880 MHz – 915 MHz | 925 MHz – 960 MHz | FDD |
| 13 | 777 MHz – 787 MHz | 746 MHz – 756 MHz | FDD |
| 17 | 704 MHz – 716 MHz | 734 MHz – 746 MHz | FDD |
| 20 | 832 MHz 862 MHz | 791 MHz 821 MHz | FDD |
| 38 | 2570 MHz – 2620 MHz | 2570 MHz – 2620 MHz | TDD |
| 40 | 2300 MHz – 2400 MHz | 2300 MHz – 2400 MHz | TDD |

NGMN Alliance agreed to a phased approach as a workable solution starting with band classes 1, 7, 13, 38, 40[1] for early deployment in 2010. In a second phase additional complementary frequency bands based on the ITDD requirements will be required in 2011.

## 2.3 TDD / FDD Terminal Chipset Solutions

The work package “TDD / FDD Terminal Chipset Solutions” of task force TD-LTE was initiated to provide some technical and cost analysis on LTE TDD / FDD single baseband chipset (use ‘BBIC’ hereafter) and single RF chipset (use ‘RFIC’ hereafter) (see Figure 3).

To satisfy the single chipset requirement, some investigations and vendor survey have been conducted in this project to evaluate the technical feasibility and cost impact. This activity started from August 2009 to address the above objectives and the work was concluded in January 2010. The final version was released in January 2010.

[1] GCF working assumption

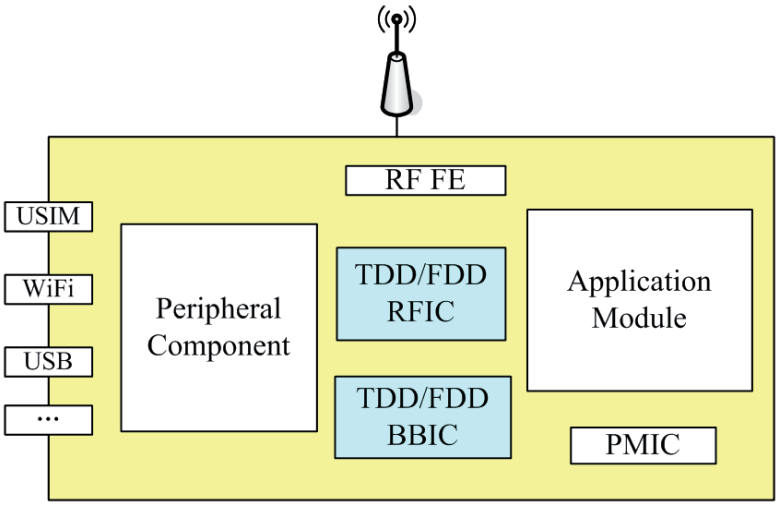



**Figure 3: General architecture for device platform**

LTE TDD/FDD single BBIC is technically feasible and cost effective, i.e. hardware and almost all the design and implementation work can be re-used. Comparing with separate TDD and FDD BBIC chipset, the cost increment mainly comes from the early R&D expenditure. Benefiting from the global scale of single LTE BBIC chipset, the total cost increment will be very limited.

Using up-to-date crafts, LTE TDD/FDD single RFIC is technically feasible. The main challenges for single RFIC come from the required number of bands and not the number of radio access technologies. It will be highly-integrated wideband RFIC covering most of the required bands. The price of the single RFIC chipset is quite dependent on the shipment volumes. The single RFIC satisfying most of the mobile technologies and bands could benefit a lot from the large scale global LTE deployment.

In order to support the investigation results, a survey was conducted in December, 2009. Seen from the feedbacks, most LTE device vendors have recognized and followed this “single chipset” product trend. All of the nine vendors (six NGMN partners and three from outside) will provide TDD/FDD single chipset products (mostly between 2Q 2010 and 2Q 2011). Eight out of nine have provisioned detailed bands and frequency information. In addition, most vendors have also considered putting EDGE / WCDMA / TD-SCDMA into the same chipset. Several vendors have clear roadmap for that.

The result of this work is publicly available on NGMN portal, “NGMN Requirements of TDD/FDD Single Chipset for LTE Device” [4].

LTE TDD/FDD single BBIC is technically feasible and cost effective. It should be mandated for LTE chipset product implementation. LTE TDD/FDD single RFIC is technically feasible, and the cost is most dependent on the shipment volumes and will benefit a lot from the global LTE deployment. Vendors are highly recommended to provide integrated single RFIC product.

## 2.4 Terminal Certification

In September 2007 a small focus team including new innovators and operators defined the initial scope of device certification. This document and a series of operator driven workshops lead to the project Terminal Certification. The NGMN project on Terminal Certification (aka P18) was initiated to significantly and sustainably improve Terminal Certification and to ensure a successful commercial launch of next generation services.

Terminal certification and conformance testing are a necessary part of the roadmap to device availability, not just something “nice to have”. A poor certification implies a lack of confidence in the commercial devices and an extra cost to the industry, since operators will require personalised testing. Furthermore, the certification process shall be completed in a timely manner to ensure the availability of reliable commercial devices. Moreover, with next generation networks new classes for user devices will be available. Next generation networks communication modules will be integrated in Consumer Electronics devices, Machine to Machine devices, laptops and portable Internet devices, etc.

In particular, to ensure the success of the next generation of mobile networks it is necessary to rreduce the risk of iterating the problems existing during the 3G launch:

- Big, bulky and very costly 3G terminals compared to state-of-the-art 2.5G terminals
- Poor standby and operation times compared to state-of-the-art 2.5G terminals
- Missing features especially in the area of 2G <-> 3G legacy interworking and thus lots of interworking problems

On the other hand, harmonisation of testing procedures is an opportunity for all the industry players to improve the entire ecosystem, since it leads to:

- reduction of multiple testing
- improved time to market
- less costs

In other words, the goal to reduce the costs for testing is to test once and use to the results anywhere:

- international certification bodies
- operators’ internal certification

This activity started formally in February 2008 to address above objectives and the work was concluded in June 2009.

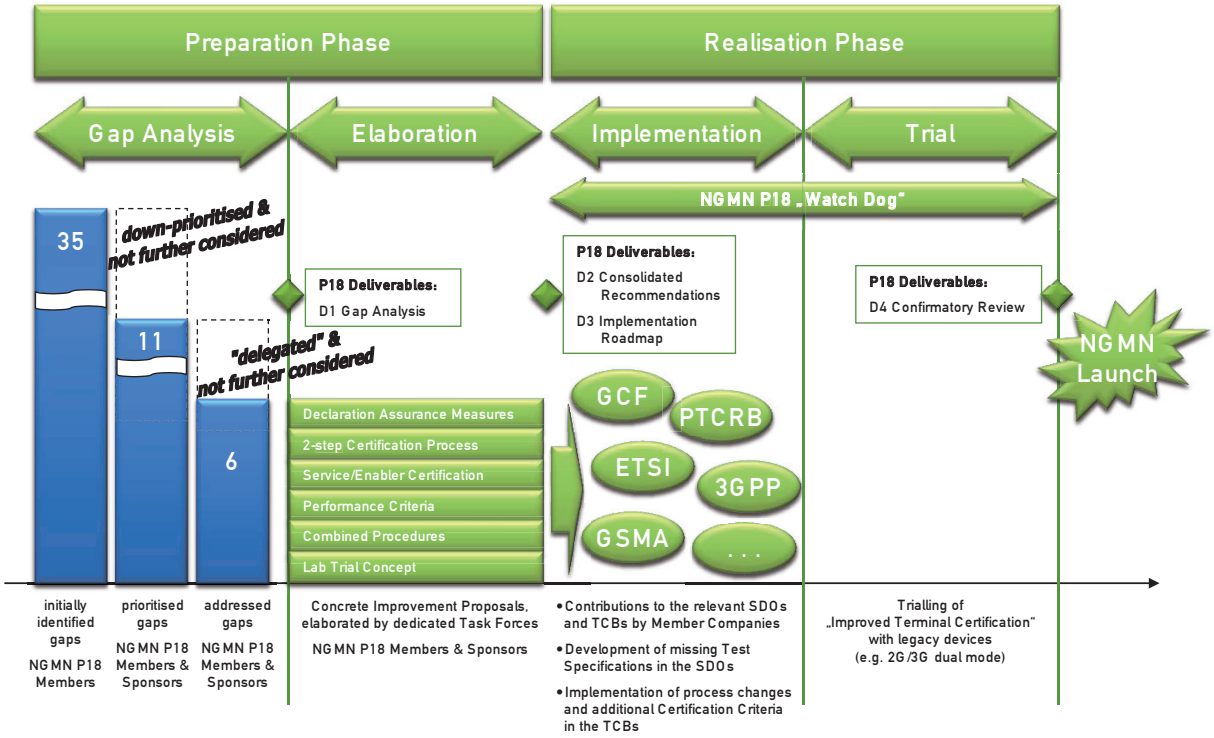



**Figure 4: Roadmap of project on Terminal Certification**

To facilitate the NGMN objective i.e. to significantly and sustainably improve Terminal Certification – a number of gaps were identified by NGMN Members and jointly prioritised and recognised with NGMN Partners in the NGMN Terminal Certification Project by a thorough Gap Analysis. This Gap Analysis was mainly focusing on gaps and weaknesses in the existing Terminal Certification Schemes, i.e. focusing on legacy technologies, but also clearly looking ahead to eliminate gaps or weaknesses in future Certification Criteria for next generation technologies.

Under the umbrella of the NGMN Terminal Certification Project, recommendation papers have been developed in dedicated Task Forces, each addressing one of the prioritized identified gaps or weaknesses and giving concrete improvement proposals of how to close respectively overcome the gaps and weaknesses. One very important NGMN delivery is the consolidated set of recommendations for Terminal Certification that has been produced in close co-operation and agreement among NGMN participating network operators, terminal manufacturers, chipset manufacturers, test equipment vendors and test houses [7].

The results of the analysis and the recommendations are focused on next generation candidate technologies, and represent the basis of input papers to the Terminal Certification Bodies on the basis of companies' inputs. An action plan of possible inputs to the Terminal Certification Bodies is provided in the deliverable "Roadmap for the improved certification (interdependencies between stakeholders)" [8] (see Figure 4).
The result of this work is available only for NGMN partners on NGMN portal, "Recommendations on necessary improvements in the current certification process" [7] , "Roadmap for the improved certification (interdependencies between stakeholders)" [8].

Specific recommendations on terminal certification are:

- Performance Criteria should be added to the current certification process. For the majority of Performance Criteria minimum requirements are to be met for terminal certification. For most of the Performance Criteria, the Certification Declaration of every individual terminal device shall contain the absolute measurement results and the absolute Measurement Uncertainty for this result.

- Declaration Confidence Assurance Measures - Any self declaration certification scheme is only as good as the quality of the processes implemented and must be able to accommodate all manufactured products that enter the supply chain. Such processes include test selection, conditions under which the tests are performed and the declaration process itself; but for any scheme to be seen as credible by third parties, certain quality messages and control measures need to be in place.
- Combined procedures end-to-end for signaling flows on layer 3, as they occur in real environments, need to be covered by relevant test specifications produced by SDOs.
- Include in the certification procedures new services and services enablers.
- Laboratory Trials should be considered by terminal certification bodies to replace and/or complement Field Trials.
- A two Step Approach for Certification - a common minimum level of tests to be passed to indicate a sufficient level of stability (RFA Quality Gate) - should be added to the terminal certification process. In such a way, operators may start internal and additional testing when devices are sufficiently stable from a certification perspective.

In October 2008 during the 1st Executive Workshop on Devices, NGMN Alliance agreed to stop the technical discussion in NGMN project terminal certification and contribute the work directly in GCF and RAN5. The participants of the workshop i.e. the operators and vendors (in GCF and other relevant fora) committed to work based on the NGMN recommendations as a valuable input and to set up a liaison process between GCF and NGMN in order to monitor the progress of work and the obtained results. NGMN Alliance set regular check points in order to allow vendors to present the obtained results in GCF and the degree of fulfillment of NGMN operator's recommendations to NGMN OC and Board. This work of addressing device certification, availability of test cases and required frequency bands for devices is still ongoing and will continue until full launch of next generation mobile networks is achieved.

## 2.5 SMS and Voice in LTE

In 2009, the mobile industry and NGMN operators were faced with several solutions to introduce SMS and Voice in LTE/EPC networks. On the one hand, not all of these solutions were fully specified or part of the 3GPP family standards but on the other hand, not all the NGMN operators had the same deployment strategy and timeline.

The need for a single solution for SMS and Voice in LTE/EPC networks was a must to ensure the roaming in LTE/EPC networks from day one.

In September 2009 NGMN OC initiated a task force to deal with the issue of SMS in LTE/ePC. This task force continued to work on voice in LTE/EPC networks from December 2009.

The scope of the work was clearly defined by NGMN OC and coordinated with GSMA to avoid duplication of work.

The NGMN task force on voice analyzed 3 migratory solutions 1) Circuit Switched Fall Back (CSFB), 2) Voice over LTE via Generic Access (VoLGA), 3) Dual Radio (turned to be a complementary solution to other migratory solutions). In addition, a document titled «Technical tasks to be performed for IMS/SRVCC» is being developed by the Task Force, in order to allow tracking of open issues with regards to target solution in NGMN.
NGMN announced at its 3rd Executive Workshop on Devices in Geneva, October 2009, the recommendation to implement "SMS only over SGs" as a minimal requirement to enable roaming from day one. NGMN agrees the following way forward:

- Desire that the UE manufacturers implement at least "SMS only over SGs" to enable roaming from Day 1. This solution is proposed because SGs requires only a new SW release deployment which seems more realistic than proposing IMS in all networks from day 1 for SMS.
- This does not preclude the implementation of "SMS over IMS".

- Other solutions are not precluded.
- Recommend implementation of the "SMS only over SGs" feature in all networks to resolve the SMS roaming issue.

NGMN announced on February 5th, 2010, that the Alliance and its members are firmly committed to IMS Voice as the target solution for Voice over LTE. Furthermore, NGMN recognises the benefits of recommending a migratory non IMS voice solution that guarantees voice roaming with LTE handsets whilst allowing use of LTE data roaming in the same device. Thus NGMN recommends that:

- In all LTE devices that support GSM or UMTS and that provide the voice service, Circuit Switched Fall Back (CSFB) shall be implemented as a minimum requirement for supporting voice. The CSFB implementation shall be compliant to the 3GPP specifications.
- If a Mobile Network Operator operates a network comprising LTE plus GSM or UMTS and if this MNO aims to provide a non-IMS voice service as well as an LTE data service to visiting subscribers utilising an LTE device, then it shall, as a minimum, support CSFB for voice. The implementation shall be compliant to 3GPP specifications.

## 2.6 Executive Workshop on Devices

Objective of the Executive Workshops on Devices are to further jointly review the current next generation device roadmap, to identify gaps to vendors'/standards' planning and to agree on an action plan. The overall goal is to ensure synchronized availability of end-user devices and network elements in 2010. Currently, the technology focus of the workshops are 3GPP LTE/EPC, future workshops could address other technologies as well.

To ensure a solid and structured basis for tracking NGMN milestones for device availability, a questionnaire was developed and adapted continuously. At the time of writing this document, 5 surveys were carried out with huge amount of vendor involvement and support (see Figure 5 ):

- 1st survey Q3-2007,
- 2nd survey Q3-2008,
- 3rd survey Q1-2009,
- 4th survey Q3-2009, and
- 5th survey Q2-2010.

The result of this work is available only for NGMN partners on NGMN portal.

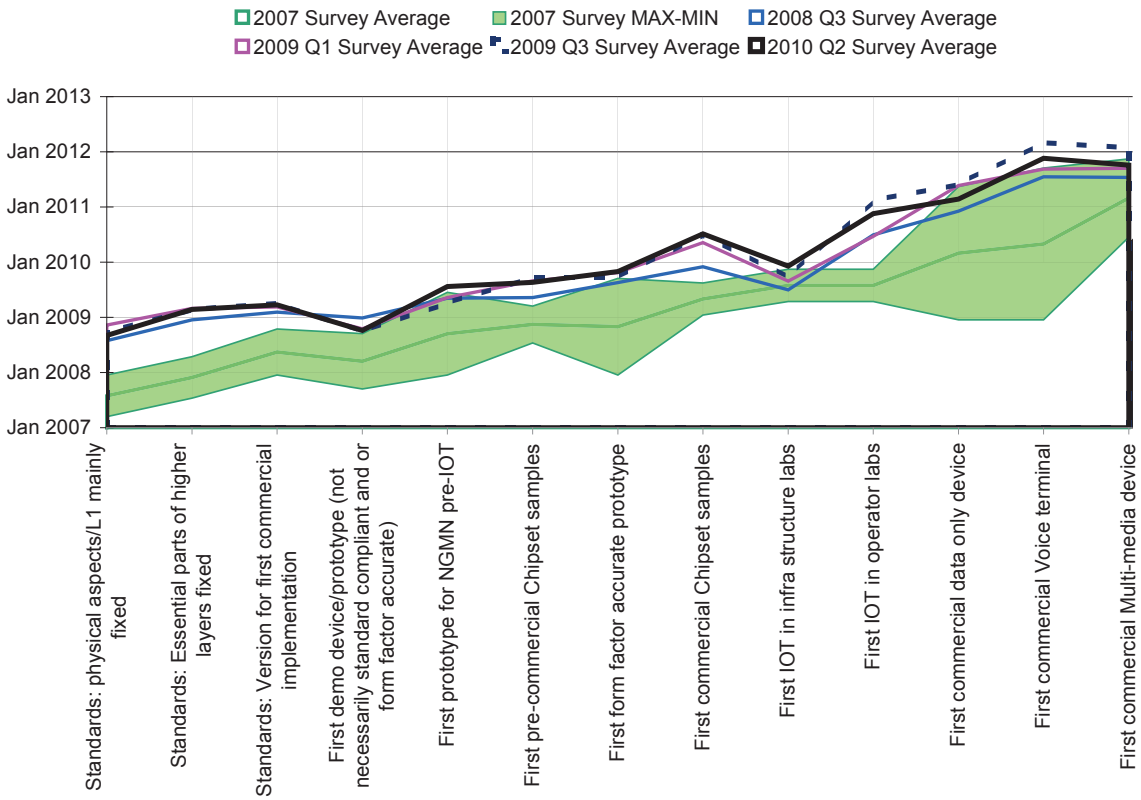



**Figure 5: Overview of survey results**

# 3 NETWORK ASPECTS

This chapter deals with technical working group activities which focus on different parts of architecture and network components and interfaces.

## 3.1 Multi-vendor RAN

The overall objective of the Multi-Vendor RAN Project (P-MVR, aka NGMN project 13) was to provide operators with the capability to purchase, deploy, operate and maintain a network consisting of Base Stations and Serving Gate Ways (SGW) from multiple vendors.

The underlying rationale for the overall objective is that seamless capability and performance is required across coverage area whose nodes are supplied by different manufacturers:

- No manufacturer has ever supplied the full range of Base Station configurations needed by an operator.
- Consolidation of manufacturers and their product lines as the industry matures.
- The ever changing regulatory and consumer environment makes future infra-structure sharing and network amalgamation almost certain.
- Best-in-class eNB, MME/SGW and OMC are extremely likely to come from different suppliers due to divergent technologies. Operators Business Case will be impacted by compromised technology performance.

- Self-Optimising Network (SON) is a “mandatory feature” from the NGMN point of view in LTE. Multi-vendor support means standardisation in measurements and outputs. These are pre-requisites for SON Optimisation and in fact most of the automated FCAPSI[2] (Fault, Configuration, Accounting, Performance, Security Interface) which are desired.

To achieve Multi-Vendor RAN capability, the following sub-objectives were identified:

- Unambiguous specification of Core Network to BTS-site interface (functional split and protocols),
- Unambiguous specification of BTS-site to BTS-site interface (functional split and protocols),
- Agreement on RAN Operations and Maintenance (O&M) architecture and unambiguous specification of relevant interfaces and functionality,
- Development of high quality handover algorithm that can be used to permit neighbouring eNodeBs to come from different vendors,
- Development of test equipment and test specifications for testing interfaces to BTS-sites and to the Serving Gateway (from the eNodeB), and
- Establishment of multi-vendor RAN test bed / test eco-system.

Full Multi-vendor capability as shown in Figure 6 was sought. This meant that equipment from different vendors was fully inter-mixed, as opposed to a restricted – geographical deployment where all equipment in a specific zone is from one vendor.

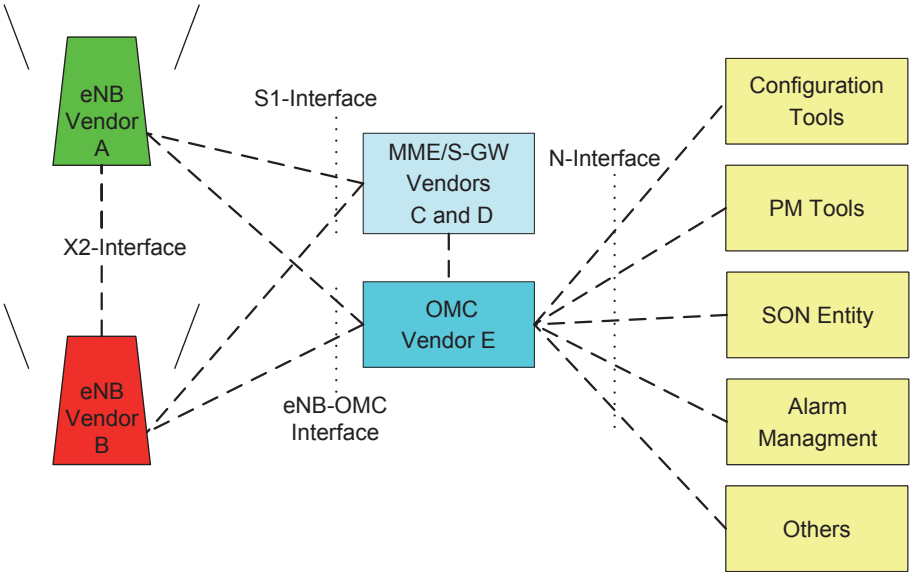



**Figure 6: Full Multi-Vendor Capability**

NGMN completed the Multi-vendor Aspects P-MVR in early 2009. The main goal of this project was to ensure the multi-vendor capabilities of the radio network interfaces and the solutions (e.g. RRM, SON, etc) provided over these interfaces in Release 8 timeframe. Secondly, the project focused on simplification of the O&M interface.

During the work for 3GPP Release 8 a high level of multi-vendor capability was successfully achieved (e.g. the interface between LTE and core network (S1-Interface) is fully standardized). Moreover the LTE internal

[2] FCAPS is an ISO model for network management and is the abbreviation for Fault Management, Configuration Management, Accounting Management, Performance Management, Security Management.

Interface (X2-Interface) was standardized and can be operated in a fully multi-vendor way. The NGMN P-MVR produced a significant number of contributions which were presented and agreed to be included into Release 8. A reference to list of contributions is available on NGMN portal.

The P-MVR was unable to achieve the agreement for a unified and standardised handover algorithm, but was able to achieve the agreement for a "Historical Information Element" on the handover protocol, which achieved most of the original objectives.

The O&M objective was partially successful with 3GPP agreeing the O&M architecture. However it was not possible to achieve a fully open southbound interface for the Element Manager to the Network Element.

The objective of establishing a multi-vendor RAN test bed was taken up most successfully by LSTI (LTE-SAE Trial Initiative) and MSF (Multi-Service Forum), who both worked very co-operatively with detailed requirements and guidance provided by the NGMN Trial Working Group.

The final report for closure of project is available on NGMN portal [9].

In order to increase the multi-vendor capability of LTE further work is needed on enhancements for the O&M System (e.g. standardisation of the open Interface between eNBs and O&M System). Further, it should be aimed to provide standardise more performance measurements to be used in the O&M system in order to be able to monitor and operate the system in a more efficient way.

## 3.2 Support of Broadcast and Multi-cast

In NGMN TWG, Project 7 "Broadcast and Multicast Support" looked into network operators' needs to support broadcast and multicast services. The key objective of Project 7 was to deliver the recommendations and requirements for broadcast and multicast services. These sets of recommendations and requirements will form the basis for equipment roadmap and evaluation criteria for next generation broadcast and multicast systems.

Project 7 identified a set of requirements for the supporting broadcast and multicast. Project 7 recognised that the support of broadcast service and/or multicast service could not be deemed as mandatory within terminals or networks. However, if the system supports broadcast and multicast, the design and implementation of broadcast and multicast shall be compliant to the requirements of this document. Furthermore Multicast is considered to be of equal significance to Broadcast.

The work of Project 7 for the support of broadcast and multicast was based on widespread involvement between a large number of NGMN members and sponsors. It reviewed operators' needs to support broadcast and multicast services and generate corresponding MBMS requirements on:

- Radio Network Requirements
- UE Requirements

The list of requirements for broadcast and multicast support is summarized below.

Network requirements:

- Re-use physical layer components
- Support transmissions: Point to multi-point, dedicated and mixed carrier; single cell and multi-cell
- Spectral efficiency of 10 times or better than 3GPP Release 6 MBMS
- Ensure continuity of broadcast and multicast services for speeds higher than 120 km/h

- Ensure phase synchronisation of sites in multi-cell single frequency network
- Support multi-operator sharing of broadcast and multicast infrastructure
- Have minimum additional interfaces due to broadcast and multicast support, and interfaces should be open and standardised
- Have architecture that is flexible and allows network expansion independent of the unicast network
- Support interaction and uplink feedback

UE requirements:

- Support reliable distribution of emergency information if unicast does not provide emergency support information which is an optional UE capability to fulfil local regulatory requirements.
- For single receiver UE, enable simultaneous reception of multiple streams of broadcast/multicast and unicast data on mixed carrier.

The result of this work is publicly available on NGMN portal, NGMN Broadcast Multicast Support [11].

A series of recommendations and requirements nail down operators' view of MBMS. This work also helps NGMN and industry (3GPP) for further consideration of MBMS.

## 3.3 Backhaul

The backhaul part is one of the most crucial blocks to make the next generation of mobile networks form the blue-print of an innovative platform for the competitive delivery of wireless broadband services that benefit customers. Without such cost-effective and bandwidth-efficient transport solutions, customers will not experience high broadband everywhere, every time. Recognising this, NGMN established a project addressing optimised solutions for backhaul (P-OSB), with the following objectives:

- Definition of requirements and assessment of innovative ALL-IP transport solutions facilitating optimum backhauling (including self-backhauling)
- Identify and make recommendation to address optimal transport and backhauling demands for the next generation of mobile networks
- Make sure partner SDO's (e.g. Broadband Forum (BBF), Metro Ethernet Forum (MEF)) cover all NGMN Backhaul requirements

The first deliverable, "NGMN Optimised Backhaul Requirements," was completed in August 2008 and defines the high level backhaul requirements to support the requirements of the Next Generation Mobile Networks. The requirements cover:

- Connectivity
- Segmentation
- Service classification
- Services aggregation
- Multicast/broadcast
- Transport resource sharing and management
- E2E service manageability and monitoring
- Multi-vendor O&M
- Synchronisation
- Reliability and fault restoration
- Performance
- Security
- Cost reduction

The Optimised Backhaul Requirements document is available on the NGMN portal [23]. It was sent to standardisation organisations working on mobile backhaul solutions (Broadband Forum (BBF), Metro Ethernet Forum (MEF)), and they were requested to take the requirements into account in their specification work.

Since 2009, the P-OSB project has been analyzing the requirements against the standardization activities in BBF and MEF to determine the gaps and identify missing enablers. This work is being carried out in eight work-streams, the first of which defined the deployment scenarios to be considered. The work-streams are:

1. Deployment scenarios (used by all other streams)
2. Dimensioning
3. Forwarding Plane & Control Plane
4. E2E QoS
5. E2E O&M
6. Security
7. High Availability
8. Synchronization

The output of the work-streams will form the basis of collaboration with the Metro Ethernet Forum as they progress Phase 2 of their Mobile Backhaul Implementation Agreement.

## 3.4 Security

The project on security (P-SEC) was initiated in NGMN TWG to clarify NGMN security requirements based on the high level description in the NGMN White Paper 3.0, to give recommendations on the security related “partly covered” and “not covered” in gap analysis results, and to co-operate with 3GPP, OMA, OMTP, GSMA etc. to address the gaps identified, considering the various security focus of these organizations (see Figure 7).

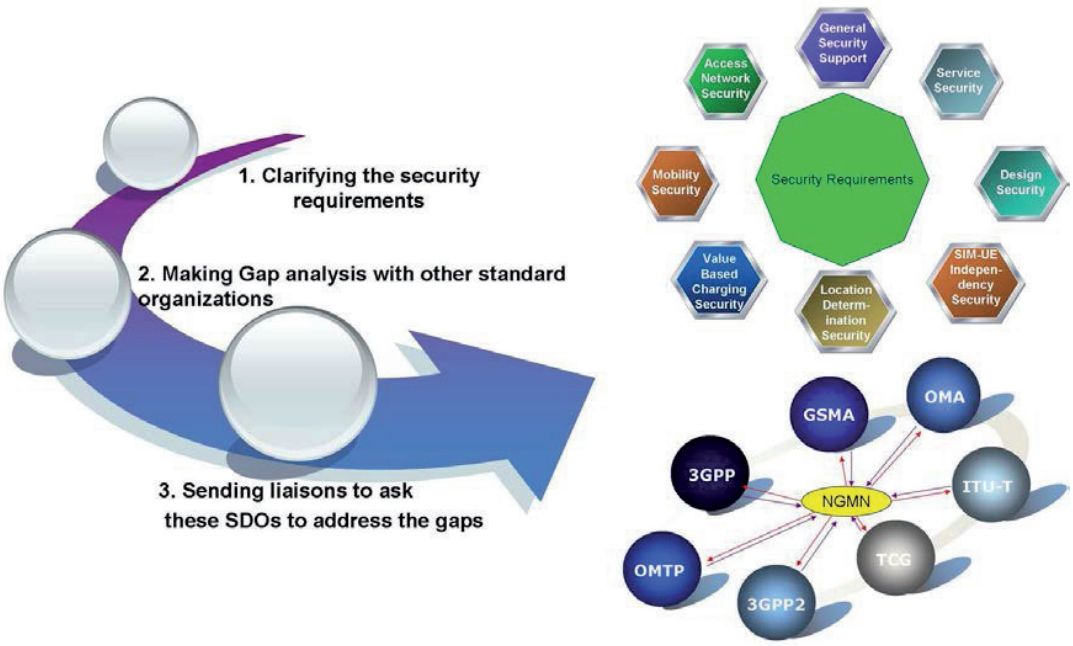



**Figure 7: Overview security project**

The deliverables of P-SEC are:

| Deliverables | Object | Time Line | Completion Status |
|---|---|---|---|
| D1 | Clarify NGMN security requirements | 2009.1-2009.3 | 100% |
| D2 | Give recommendations on the security | 2009.4-2009.6 | 100% |
| D3 | Contributions and liaisons to related organizations | 2009.7-2009.12 | 100% |

The results and achievements of P-SEC are:

1. All security requirements were discussed and clarified one by one.
2. Security gaps between NGMN and related SDOs such as 3GPP, GSMA, etc. were analyzed for these requirements.
3. Many dissemination activities were made inside and outside the NGMN.
4. More than 40 related contributions were made, such as project schedules, draft baselines, discussion papers, LSs to related SDOs.

The final report for closure of project is available on NGMN portal [10].

The guidance on implementations are as following:

- Next generation mobile networks shall provide the integrity of the signalling over the access network.
- Support authentication and secure routing (e.g., IPSec for IP traffic) of 3rd party access signalling to operator's network.
- Next generation mobile networks shall support the ability to securely connect to the Next generation mobile networks core via un-trusted and trusted access in the reformulation.
- Provide mechanisms to ensure the interception of signalling and user generated traffic (e.g. media stream, data files) per legal intercept requirements in a given locale.
- Provide end-to-end security between the device to service platform and end-to-end security between user-to -user (e.g., security for the voice, messaging, etc). Signalling is mandatory, UP traffic is optional.
- Terminals shall provide comprehensive platform security features to protect against malware which minimize the impact on user experience
- Provide network protection from malware.
- The communication and the near field communication path between SIM and UEs must be secure and the protocol used for security must be easily integrated into all devices, and in particular, consumer electronic devices.
- Mobility management of inter and intra Radio Access Technology handovers shall be secure
- Support mutual authentication and authorization of subscriber and operator network
- Next generation mobile networks shall provide confidentiality protection of user identity and location against passive attacks on the access network.
- Provide that authorized users have access to information and assets whenever required
- Next generation mobile networks shall support the use of operator's security credentials (e.g., those stored on the smartcard) for the authentication and authorization (e.g. EAP-AKA, GBA) of the final customer while accessing 3rd party access networks.
- Secure access to operator services shall not rely on bearer security and access network security services
- Provide a single sign on mechanisms to access a service without reducing the overall security

## 3.5 Operational Efficiency

Setting up and running networks is a complex task that requires many activities, including planning, configuration, optimisation, dimensioning, tuning, testing, recovery from failures, failure mitigation, healing and maintenance. These activities are critical to successful network operation and today they are extremely labour-intensive and hence, costly, prone to errors, and can result in customer dissatisfaction. This project on operational efficiency (P-OPE) focuses on ensuring that the operators' requirements are incorporated into the specification of the 3GPP O&M (and similar groups in other standardisation bodies) so that this critical task moves towards full automation.

The overall objective is to provide operators with the capability to purchase, deploy, operate and maintain a network consisting of Base Stations (BTS) and "Access Gateways (AGw)" from multiple vendors.

To keep on fulfilling these NGMN White Paper 3.0 requirements on SON, O&M and Multi-Vendor Support the following sub-tasks were defined:

- improve procedural efficiency, increase network capacity and quality of service, address new technological issues, evolve the operational processes
- to progress on further SON use cases
- to pursue standardisation O&M interfaces to get a true multi-vendor O&M system
- to study all HeNB-Macro operational use cases (migration between different releases, interference coordination, load balancing, etc)

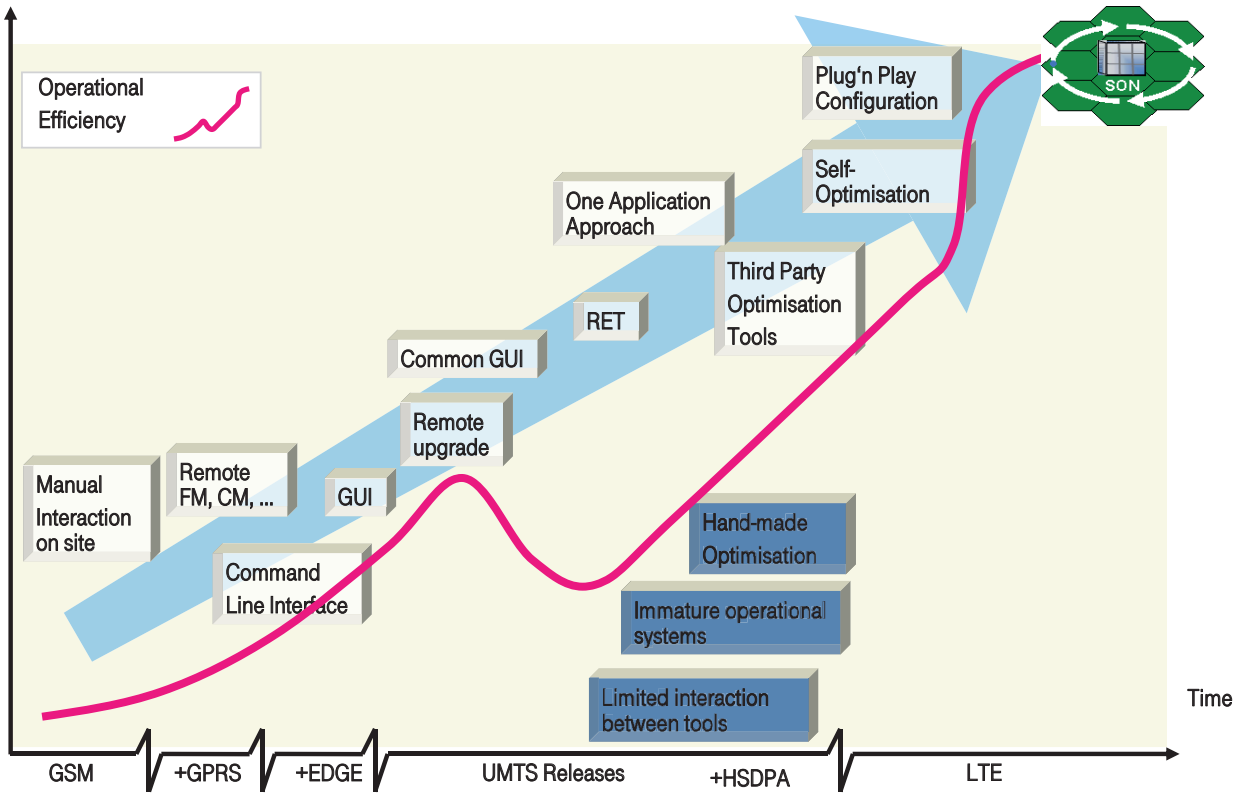



**Figure 8: Operational efficiency development**

1. Nine sub-projects were setup related to SON use cases; 3 clusters were defined to formulate O&M related positions to push operational efficiency.

2. For all these SON sub-projects or clusters feasibility was analysed and concept ideas were worked out.
3. For the O&M related clusters operator opinions/targets and a way forward is described to enable multi-vendor efficient O&M standardisation.
4. All these projects are documented by delivery documents or position papers.
5. Many dissemination activities were made inside and outside the NGMN Alliance.
6. Standardization positions and recommendations were worked out and have impacted 3GPP Release 9 standardization and is considered for 3GPP Release 10 planning.

NGMN worked on SON in a former project P-SON in 2007 and 2008. The results of this work can be found on NGMN portal. The deliverables are “NGMN Use Cases related to Self-organising Network, Overall Description” [12], “NGMN recommendation on SON & O&M requirements“ [13], “NGMN Informative List of SON Use Cases” [14]. The results of P-OPE “NGMN TOP OPE recommendations”[25] are published on the NGMN public webpage.

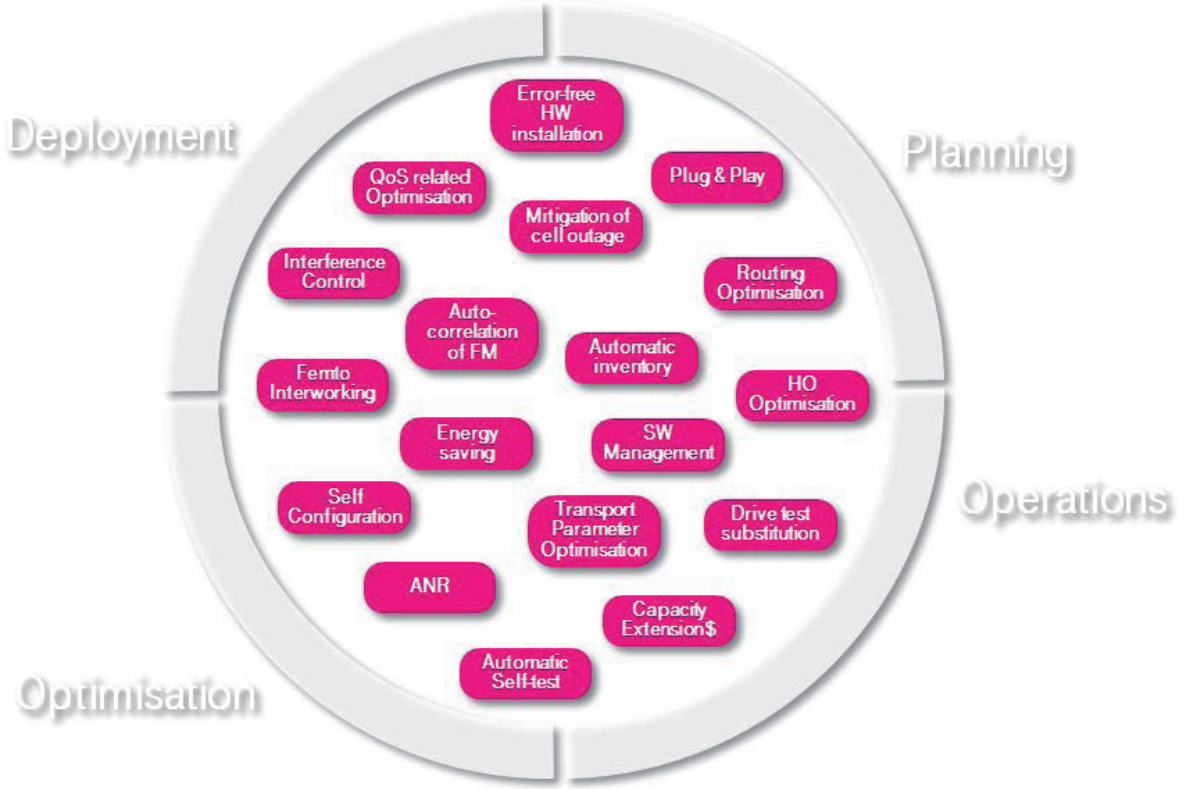



**Figure 9: Some of the important use-cases that need to be addressed to ensure SON**

Generally, NGMN offers a platform to develop proposals together for standards and recommendations for implementations. In the following a high level view is given on concrete recommendations:

- Recommendations for some use cases to support distributed functionality by appropriate interface definitions (e.g. load balancing, HO optimization)
- Recommendations on UE support and location information for drive test substitution
- Recommendations on Interaction of Home and Home BTS use cases
- Recommendations for centralized (but not excluding distributed) solutions to cover energy saving and channel optimisation use cases
- Push for NGOSS and SOA
- Recommendations to handle SA5 IRPs (Integration Reference Point)
- Recommendations to standardise deployment & optimisation processes

- Recommendations on first enablers SON for other use cases like QoS optimisation, SON in core Network and cell outage compensation

There are two parts of the Operational Efficiency project, SON and O&M:

- SON was built to further enhance the requirement spectrum and has formulated use cases.
- O&M has outlined direct recommendations (e.g. standardized interfaces & themes such as NG-OSS, efficient groupings, optimized modeling, plug & play etc.) applicable to specific cases.

The NGMN Top OPE requirements (see picture below) are natural and specific consequences of Open O&M and SON formulation, while using their content to future mature each area.

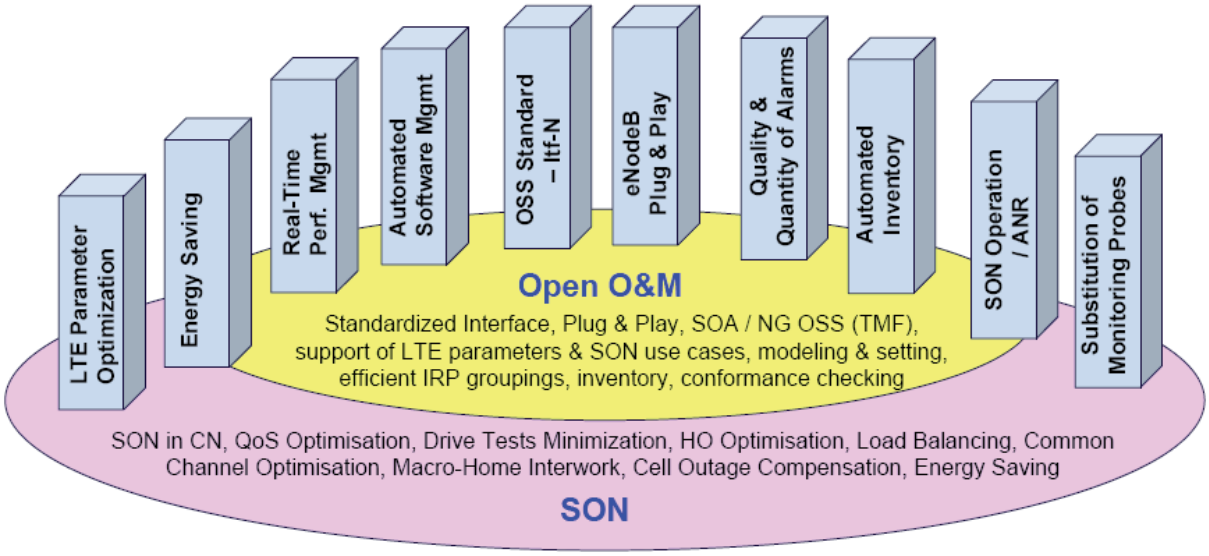



**Figure 10: NGMN Top OPE requirements relation to SON and O&M**

## 3.6 Database Convergence

Currently in mobile networks, user data is stored in various systems (silo approach), i.e. the same data element is stored in many places. And the data is only accessible by the application linked to that data base (see Figure 10). NGMN Whitepaper 3.0 recommends one logical real-time data base storing all user data (user data centric approach).

To facilitate the NGMN specification, the project on database convergence (P-DC, aka project 17) was initiated with the following objectives:

- Consolidation of NGMN operator requirements and benefits of user data centric approach
- Evaluation of cost reduction potential (CAPEX/OPEX)
- Definition and standardization of adaptation functions between database and applications
- Influence and motivation of main application/service suppliers
- Time to market: significant reduction of development effort for new applications/services
- Massive simplification of operation, management and maintenance

At the 3GPP SA1 #40 meeting, the WI “User Data Convergence” was agreed (S1-080764). SA plenary agreed the SA1 work item "User Data Convergence" and a successful dissemination of the project results was achieved.

Final Version 1.0 of “D1 Requirements / D2 Cost Reduction Potentials” has been published internally for NGMN operators and suppliers for information [15].

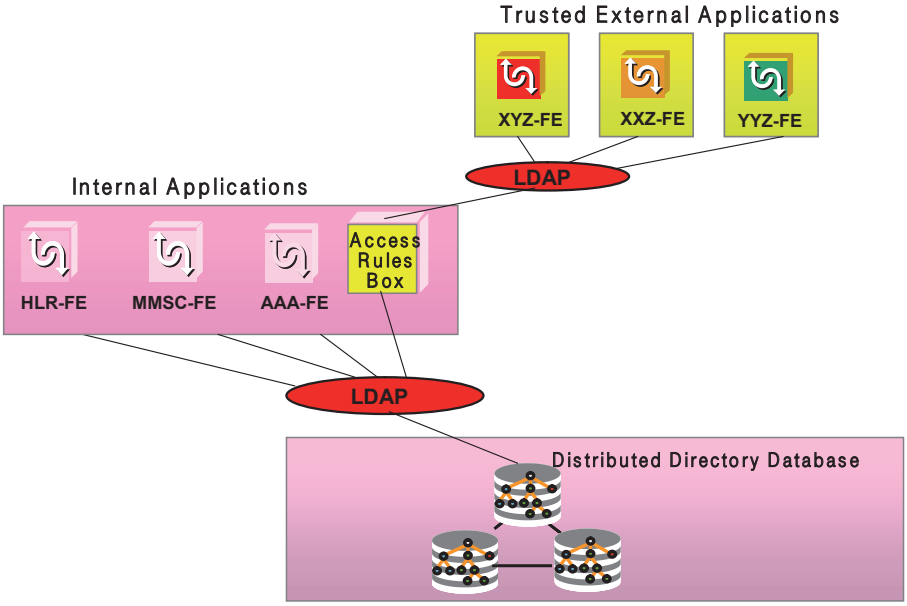



**Figure 11: Recommended Target Architecture**

## 3.7 Open Interface between Base Band Unit and Remote Radio Head

Mobile communication networks have evolved from 1st to 3rd generation, and now, many operators are preparing to introduce LTE. Economical and efficient deployment of base stations is one of key issues for the success of mobile services. Operators also consider ecological aspects when renewing a system.

In general mobile radio base stations consist of a Base Band Unit (BBU) and a Radio Frequency Unit (RFU), which usually is a Remote Radio Head (RRH) in distributed base station architecture. In order to gain flexibility, operators are looking for distributed base station architectures where the BBUs and RRH are physically separate in deployment, hence needing a physical interface between them. Current interfaces between BBU and RRH are provided in a “semi proprietary” nature, although based on industry standards like CPRI or OBSAI. In order to gain interoperability, BBU and RRH preferably should inter-connect via an open BBU-RRH Interface for more flexibility in the selection of BBU vendor and RRH vendor.

The NGMN project on open BBU-RRH interface (P-OBRI) was initiated to develop an Implementation Recommendation (IR) for interfaces between Base Band Unit (BBU), more generically defined as 'Radio Equipment Control' (REC), and Remote Radio Head (RRH), more generically defined as 'Radio Equipment' (RE), that support main radio technologies, multiplexing of different radio technologies, typical base line reference topologies, and data rate for the most common antenna configurations.

The preparation phase of this activity started as a task force in September 2008. The project started in May 2009 and drafted the OBRI Implementation Requirements (IR) which focuses on 3GPP radio access technologies, UTRA-FDD, E-UTRA-FDD and E-UTRA-TDD as well as multiplexing between UTRA-FDD and E-UTRA-FDD.

The OBRI IR complies with CPRI specification version 4.1 of CPRI forum. It has defined recommendations of layer 1, layer 2, and in addition layer 3 C&M aspects, which are not specified in the CPRI specification.

The mandatory protocol stack is shown in Figure 1. With regards to C&M Application Part, the OBRI project has developed functionality needed for activation of the REC-RE communication, as well as functions for operation and maintenance of the RE and communication between REC and RE. The OBRI project has further discussed relevant sequences, message format and coding.

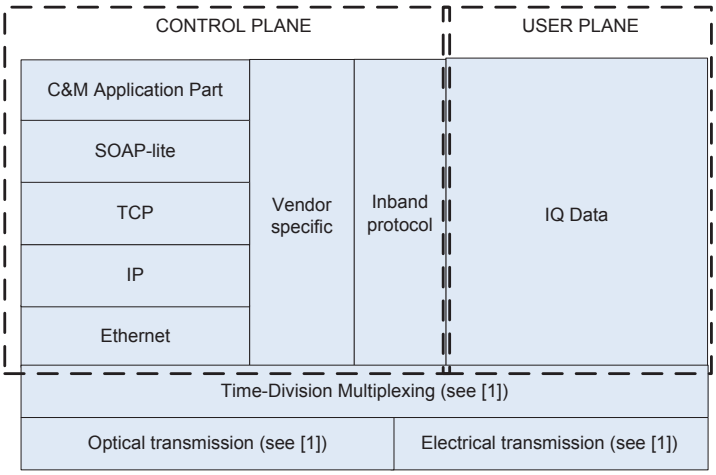



**Figure 12: Mandatory Protocol Stack for OBRI**

And the following topologies have been addressed. Chain topology is only hardware-supported by OBRI currently.

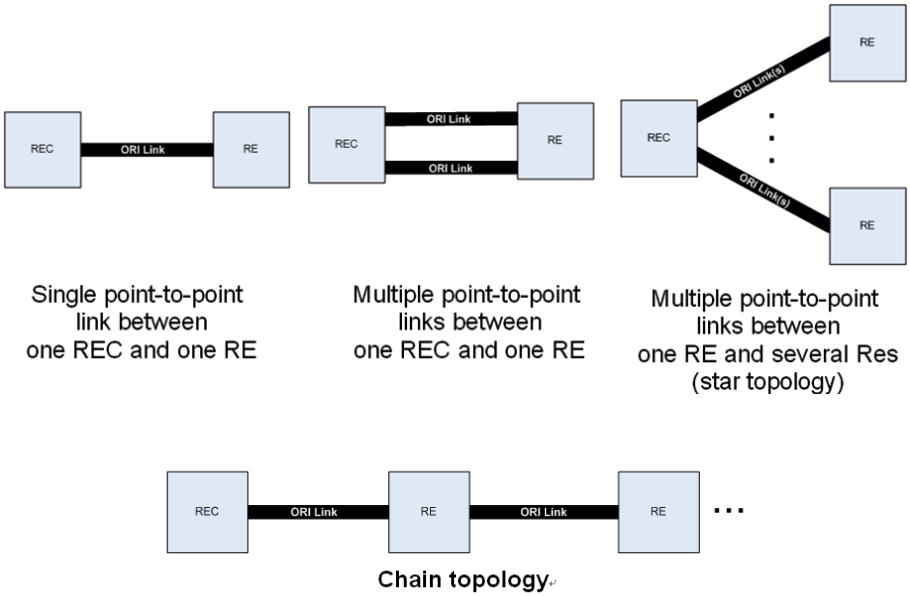



**Figure 13: Topologies addressed in OBRI**

In April 2010, the companies contributing on the NGMN OBRI project successfully setup an ETSI ISG called “ORI” (Open Radio equipment Interface) in order to succeed the activity of the OBRI project. In May 2010, the NGMN

OBRI project compiled and submitted the draft OBRI IR to ETSI ISG ORI as a baseline document for further development. ETSI ORI has now taken over the development work to finalise the specification of the OBRI interface.

The initially planned work within ETSI ORI is to finalise the specification of the topologies/RATs that have been addressed within OBRI, including the hardware support for the "chain topology". GSM support and any additional software-related support needed for chain topology are the features envisioned to be treated by ETSI ORI once specification of the initial work is completed.

The result of the NGMN OBRI work is available only for NGMN partners. All operators and vendors interested in contributing to finalise the new open interface are invited to join ETSI ISG ORI; for more information, please refer to http://portal.etsi.org/ori .

NGMN operators seek to require equipments based on OBRI/ORI, because it improves flexibility in placement of BBU and allow to get rid of the costly RF cabling. In addition, OBRI/ORI is understood to decrease the implementation and testing effort for equipment vendors. Test equipment suppliers are able to limit number of different variants for the interface. OBRI/ORI allows the industry to establish cost effective wireless broadband services for the benefit of its customers.

# 4 TECHNOLOGY EVALUATION

In H1 2007, NGMN embarked on a technology evaluation of LTE, IEEE 802.16e and UMB. This evaluation covered four areas:

- Performance
- Functionality
- Interworking (e.g. with legacy systems)
- Time-to-market

This evaluation was completed in Q1 2008. Since then, NGMN has also completed an assessment of typical user data rates, and an evaluation of TD-LTE system performance.

## 4.1 Methodology

Different standardisation bodies addressing systems within the scope of NGMN have developed their own set of metrics and evaluation scenarios, which makes it difficult to perform a reasonably fair "apples with apples" comparison of the performance of different technologies. Also, these evaluation methodologies are not always completely defined or consistent, leading to large variations of results even if different contributing companies simulate the same technology with the same methodology.

The objectives of the NGMN Radio Access Performance Methodology were to allow evaluation of the performance of different next generation system proposals under the same conditions, and to align the evaluation parameters of different partners developing the same technology. This facilitates a fair comparison of the performance of different technologies based on evaluation results from different partners.

The NGMN performance methodology provides a more detailed definition of the high-level metrics in the NGMN Whitepaper and defines a common set of evaluation scenarios. These metrics were intended to reflect the user experience and operator requirements as closely as possible whilst being reasonably easy to be assessed by simulations and trials.

Organizations such as 3GPP, 3GPP2, and IEEE, have developed performance requirements and evaluation methodologies. The NGMN methodology re-uses metrics and scenarios from these standardisation initiatives wherever appropriate, but, being technology-agnostic, specifies only metrics and scenarios and not the elements of the technology itself (e.g. which modulation and coding scheme).
The NGMN performance methodology includes the following metrics:

- Peak user data rate
- Throughput
- Spectral efficiency
- VoIP capacity
- Broadcast transmission throughout, spectral efficiency and maximum inter-site distance
- Latency (including connection setup, radio access transmission and end-to-end latency)
- Handover interruption time (within one next generation mobile network system and to another system)

The NGMN performance methodology also defines deployment scenarios and traffic models in order to achieve comparable performance results among different standards, standard proposals and vendor solutions.

The NGMN Radio Access Performance Methodology was published in Q1 2008, and can be downloaded from the NGMN Portal [16]. It was used for the performance evaluation in NGMN of LTE and IEEE 802.16e, and has been made publicly available to encourage future evaluations (for example, in ITU) to take a similar approach and ensure fair comparison of different technologies.

## 4.2 Evaluation of LTE and IEEE 802.16e

The Technical Working Group (TWG) within NGMN initiated a technology evaluation activity in 2007. The purpose of this activity was to compare various aspects of emerging technologies and assess them against the NGMN recommendations in NGMN White Paper 3.0.

The emerging technologies under evaluation where:

- 3GPP LTE (FDD / TDD)
- Mobile WiMAX (IEEE 802.16e wave 2, IEEE 802.16m) (FDD / TDD)
- 3GPP2 UMB (FDD / TDD)

The Technology Evaluation activity was organised in 4 work packages (WP):

**WP1: Performance** (see 4.1for the methodology)

This work package was considering the radio performance aspects of LTE, WiMAX and UMB. Specifically it was comparing the key radio performance metrics of peak bit rate, average cell/user throughputs, spectrum efficiency, control & user plane latencies and VoIP capacity, for each of these systems using the NGMN evaluation methodology. The main objective was to investigate whether they meet the main radio performance recommendations of the NGMN White Paper 3.0. It was not the intention to compare each technology against each other even though this is an inevitable outcome of this work package. The results of this work package were published internally for NGMN partners only [17].

**WP2: Functionality**

This work package was evaluating the candidate technologies to determine how closely they meet the NGMN functional requirements. The target was to produce a report containing the analysis and recommendation of the candidate technologies' functional capabilities. This work package was finally concluded into a detailed Gap Analysis.

**WP3: Inter-working and Migration**

This work package was evaluating the inter-working and migration aspects of the different access technologies, e.g. the impacts on legacy systems and terminal complexity when supporting both, the new and legacy access technologies against the recommendations in the NGMN White Paper 3.0 (section 4.1.1 and 4.1.2).

**WP4: Time-to-Market (incl. Terminals)**

This work package was comparing the time schedules of LTE, WiMAX (and subsequent enhancements) and 3GPP2 UMB against the roadmap as laid out in the NGMN recommendations. The assessment was based on the components in the process of system introduction and deployment for new technologies covering the Standardisation in SDOs and the product availability for Infrastructure systems and User equipment. This work package was based on a questionnaire to NGMN partners to get solid base for the evaluation. The results of this work package were used to structure the Executive Workshops on Devices.

**Board Resolution**

Based on the work done the NGMN Alliance Board took the decision June 2008 that "Based on the results of technology evaluation, the board concludes that:

1. Based on the results of technology evaluation, the board concludes that LTE/SAE is the first technology which broadly meets the NGMN recommendations. The NGMN Alliance therefore approves LTE/SAE as its first compliant technology.
2. The NGMN Alliance discontinues its work on UMB as an NGMN candidate technology"

## 4.3 Typical User Data Rate

The mobile internet has been a huge success in recent years based on 3G technologies, and next generation technologies such as LTE offer substantially increased peak and average data rates with higher network capacities. Commonly, the peak data rate is used to characterize the user data rate performance of a technology, but this often does not reflect the data rate users actually experience. The data rate that can be supported over the radio link is usually constrained to a much lower value, with two key dependencies:

- the location of a terminal in a cell affecting the quality of the radio channel (see Figure 13)
- the loading in the network, influencing the degree of sharing of radio resources with other users of the cell as well as the interference levels (see Figure 14).

The user data rate offered by mobile data networks depends upon a large number of different factors, some not related to the radio interface (e.g. backhaul, QoS prioritisation, internet, application server). In this study we consider the fundamental constraints to the user data rate arising from the radio interface, and how these cause large variations in the data rate depending upon the user location and network load [18].

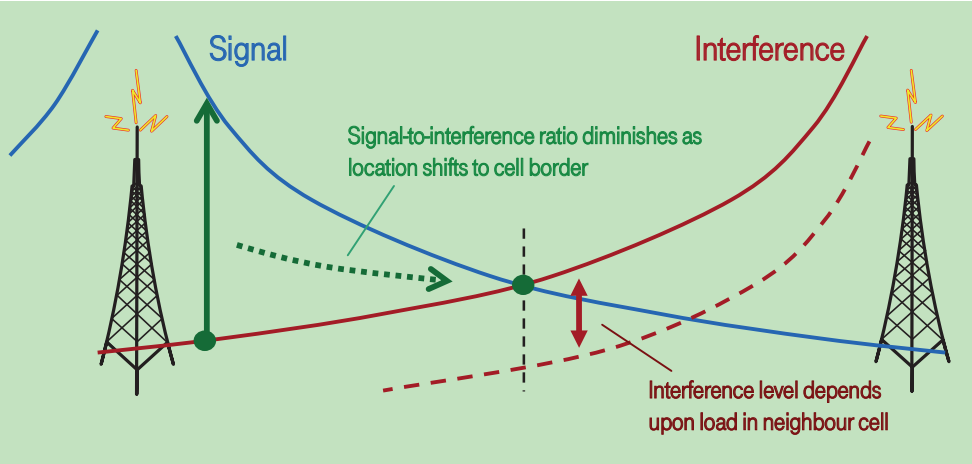



**Figure 14: Variation of signal to interference ratio with location in the cell**

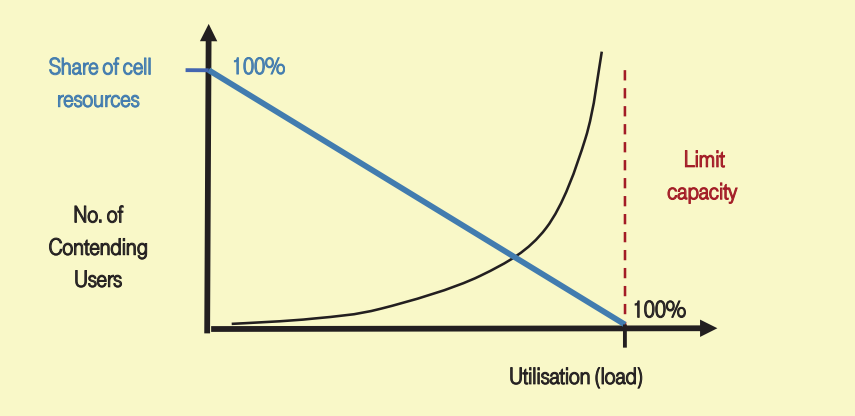



**Figure 15: Sharing of cell resources depending upon load**

The way the location and traffic load influence the user data rate is summarised in the Figure 15. The user data rate is determined by two factors: the SINR ratio and the share of cell resources, these factors themselves depend upon the user location and the traffic loading.

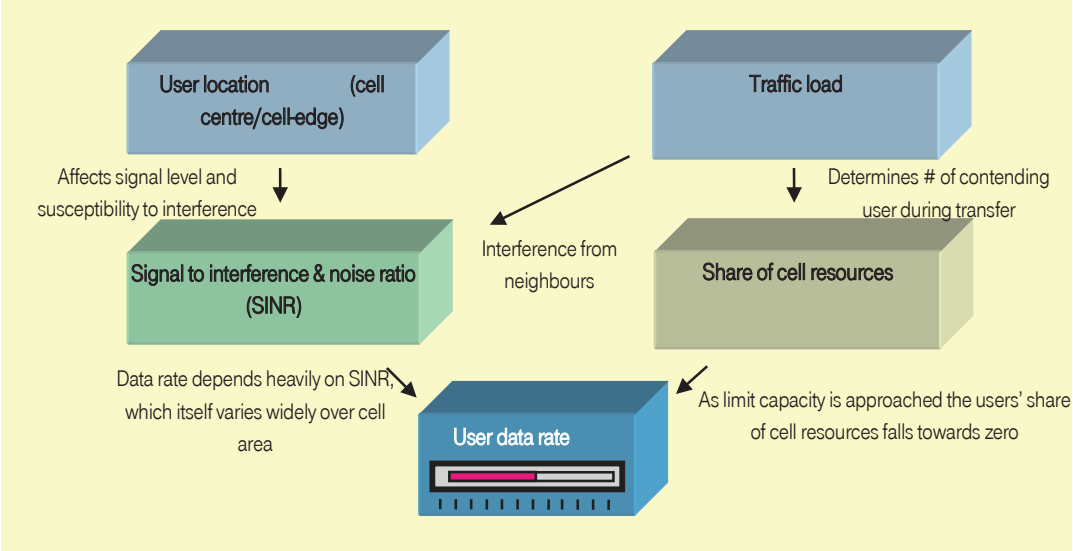



**Figure 16: Illustration of how location and loading impact the user data rate**

File transfer simulations can be used to characterise the user data rate dependencies discussed in the previous section. Recently a large number of such simulations have been performance in an industry wide evaluation of typical user data rate for LTE and HSPA technologies [19] [20].

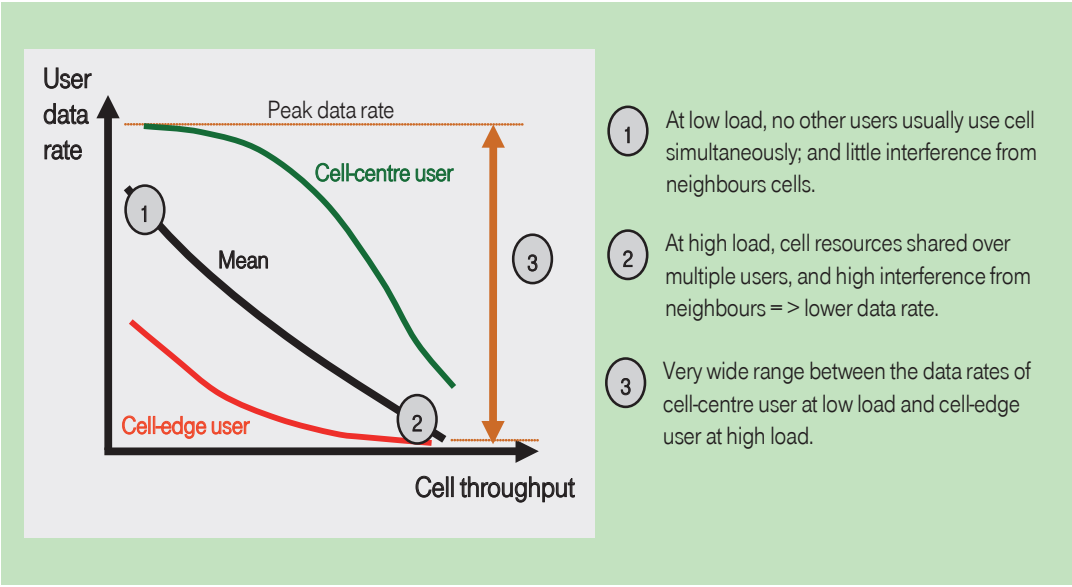



**Figure 17: Illustrative result from file transfer simulations**

The results show that as the cell throughput loading increases, the mean, cell edge and cell centre data rate all decrease substantially. Furthermore, at a particular cell throughput loading a wide spread in performance is seen between the cell edge and the cell centre users.

In order that the user data rate for different technology options can be compared in a straightforward way, *a typical user data rate* definition has been proposed as representing an indicative user data rate in a reasonably well

utilised network. The typical user data rate is the mean user data rate for a cell throughput level that results in a 50% utilisation of the cells resources.

The typical user data rate only represents an indicative performance level of networks at a certain consistent fractional load level, but it cannot be considered representative of all actual networks where a variety of loading levels exist.

## 4.4 TD-LTE System Performance Evaluation

LTE includes both FDD and TDD version. To ensure FDD/TDD converged and synchronized development, in July 2009 NGMN OC meeting decided to establish a task force to investigate key areas of FDD/TDD converged development and provide industry reference and guideline to develop FDD/TDD converged solutions. This work package introduces the further evaluation work conducted in TD-LTE Task Force.

OFDMA (Orthogonal Frequency-Division Multiple Access) / SC-FDMA Single Carrier Frequency Division Multiple Access) and MIMO (Multiple Input & Multiple Output) techniques are adopted in LTE system as the fundamental physical layer technologies. For TDD system, the uplink and downlink shares the same carrier frequency, the channel reciprocity can be guaranteed within the coherent time. And thus the channel reciprocity of TDD system can be made full use to improve the system capability. So for TD-LTE system, besides the MIMO modes supported by FDD, e.g. codebook based pre-coding, SFBC, beam-forming based on channel reciprocity is also supported.

The performance of TD-LTE with different MIMO mode and antenna configurations is evaluated on system level with the same simulation assumption as been done in 3GPP. Two rings with 19 cells service area model are assumed, each sector serves averagely 10 users. The proportional fair frequency-selective scheduling is applied to maintain the user fairness. To show the different performance with different configurations, 5 cases are evaluated for TD-LTE with 10 MHz bandwidth. The results of cell average spectral efficiency and cell edge spectral efficiency in these cases are shown in the following Figure 17, and Figure 18.

Downlink:

- Case 1: Codebook based pre-coding, 2x2 MIMO (rank adaptive)
- Case 2: Codebook based pre-coding, 4x2 MIMO (rank adaptive)
- Case 3: Eigen based Beam-forming (EBB, also named as Non-codebook based pre-coding), 4x2 single stream beam-forming.
- Case 4: Eigen based Beam-forming (EBB, also named as Non-codebook based pre-coding), 8x2 single stream beam-forming.
- Case 5: Multi-user Beam-forming.

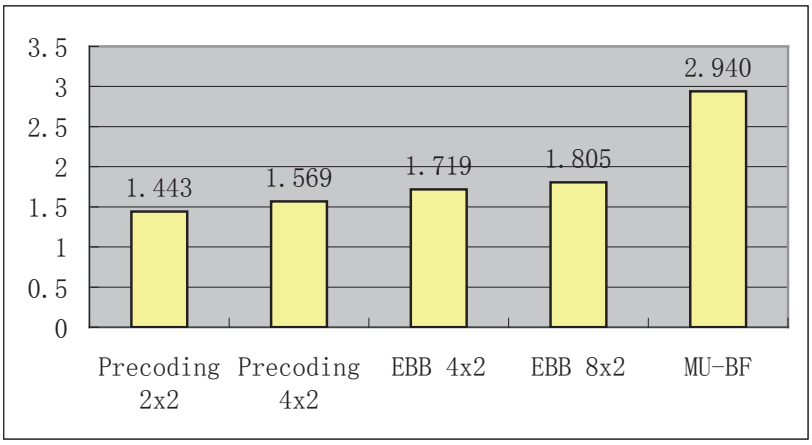



**Figure 18: Cell Average Spectral Efficiency (bit/s/Hz/sector) of TD-LTE**

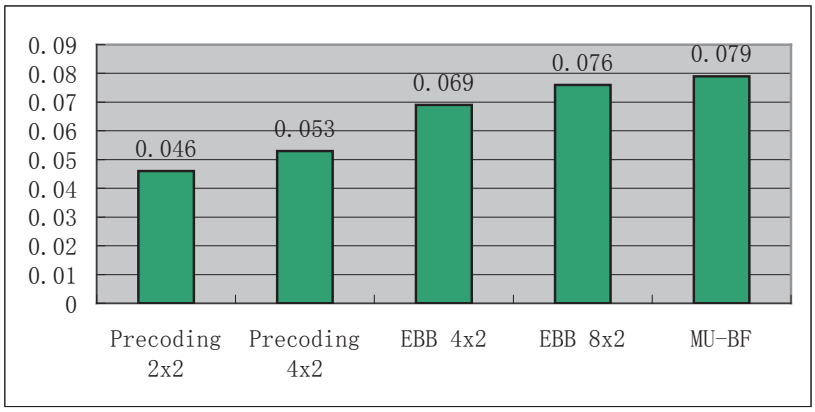



**Figure 19: Cell Edge Spectral Efficiency (bit/s/Hz/sector) of TD-LTE**

From above figures, the system spectrum efficiency can be improved by more antennas, compared to 2x2, 4x2 codebook based pre-coding performs better about 8.7% in cell average spectral efficiency and 15.2% in cell edge spectral efficiency.
When the channel reciprocity of TDD system is utilized by EBB, the system performance is further improved. Especially compared to 2x2 codebook based pre-coding, EBB 8x2 can improve the cell average spectral efficiency by 25% and the cell edge spectral efficiency by 65%.

If multi-user beam-forming is taken into account, the cell average spectral efficiency and the cell edge spectral efficiency can achieve 2.94 bit/s/Hz and 0.079 bit/s/Hz respectively, which means about 50% and 30% further gain respectively.

Based on the evaluated results above, TD-LTE has shown the attractive system capability, especially with EBB based on TDD channel reciprocity.

The results of this taskforce are publicly available and can be found on NGMN portal.

# 5 SDOS AND NGMN ALIGNMENT (3GPP)

The project was established at the beginning of NGMN initiative, with the objective of monitoring and steering the progress of the standardization activity in 3GPP, verifying the fulfillment of NGMN requirements by the LTE/SAE system and proposing actions towards the relevant 3GPP Technical Specification Groups and Working Groups.

The first phase of the activity was focused on ensuring that the technical content of the 3GPP Release-8 Core Specification was in line with NGMN technical expectations and available by end of 2008 and further consolidated by the completion of Testing Specification in 3GPP and Test Cases implementation in GCF.

Within the SAE area, the project was used to drive significant re-architecting of the 3GPP system, e.g. the movement of user plane encryption from the SGW to the eNodeB, and, the agreement on the target S4-SGSN architecture. Agreements on 'option reduction' for SRVCC were also achieved.

For Release-9, particular focus was put to introduce enhancement to LTE/SAE in the areas of SON and Operational Efficiency, mobility for Closed Subscriber Group, CSFB enhancements.

For Release-10, main targets are the development of LTE-A features, introduction of Relays, support for Machine Type Communications and further improvements of features related to SON and Operational Efficiency (in line with the outcome of the related P-OPE project).

In the project key milestones has been established and monitored to ensure that deviation from target dates are addressed and solutions mitigated.

| **Milestone** | **Description** | **Target Date** (Month/Year) |
|---|---|---|
| M1 | TG1 approved (by OC and NGMN Board). | |
| M2 | Evaluation of LTE performance | 12/07 |
| M3 | Approval of LTE Layer 1 specifications | 09/07 |
| M4 | Completion of LTE Layer 1 specifications (i.e. only corrections allowed) | 12/07 |
| M5 | Approval of E-UTRAN signalling specifications | 12/07 |
| M6 | Completion of E-UTRAN signalling specifications | 12/08 |
| M7 | Approval of 23.401 (GTP based variant of stage 2 for SAE) at SA TSG #37 | 12/07 |
| M8 | Approval of 23.402 (IETF based variant of stage 2 for SAE) at SA TSG #37 | 12/07 |
| M9 | Approval of CT stage 3 specifications at CT TSG #41 | 09/08 |
| M10 | Completion of 'essential' parts of 23.401 (see SP-070699 plus Single Radio VCC) | 06/08 |
| M11 | Completion of 'essential' parts of 23.402 (see SP-070699 plus generic non-3GPP access) | 06/08 |
| M12 | Completion of CT stage 3 specifications | 12/08 |
| M13.1 | Re SP-070699, completion of release 9 parts of 23.401 and 23.402 (e.g., Location Services, emergency calls) at stage 2 level | 06/09 |
| M13.1 | Re SP-070699, completion of Location Services, emergency calls, etc, at stage 3 level | 03/10 |
| M14.fdd | Completion of RF conformance tests for FDD | 09/2009 |
| M14.tdd | Completion of RF conformance tests for TDD | 09/2009 |
| M15 | Completion of Protocol conformance test specifications (RAN5) for E-UTRAN capable mobiles (prose description) | 09/2009 |
| M15.1p | Completion of prose description for priority 1 signalling tests | 03/2009 |
| M15.1t | Completion of TTCN description for priority 1 signalling tests | 07/2009 |
| M15.2p | Completion of prose description for priority 2 signalling tests | 06/2009 |
| M15.2t | Completion of TTCN description for priority 2 signalling tests | 12/2009 |

| | | |
|---|---|---|
| M15.v | Verification and validation of tests cases in order for GCF certification to start | 12/2010 |
| M16 | Completion of LTE-Advance study item | 03/2010 |
| M17 | Completion of specifications for Carrier Aggregation | 12/2010 |
| M18 | Completion of specifications for Enhanced Downlink Multiple Antenna Transmission | 12/2010 |
| M19 | Completion of specifications for UL multiple antenna transmission | 12/2010 |
| M20 | Completion of Relays specifications | 12/2010 |
| M21 | Completion of specifications for RAN solutions for Operational Efficiency (SON, MDT) | 12/2010 |
| M22 | Completion of specifications for Latency Reduction for LTE | 12/2010 |
| M23 | Enhanced ICIC | 12/2010 |

The resulting actions for mitigations have been individual contributions by the NGMN member companies into 3GPP with cosigning NGMN partners and often also cosigning with non NGMN companies.

# 6 TRIALS, TESTING, MEASUREMENT ASPECTS

NGMN recognizes that trial and validation activities are vital to accelerate the development of the next generation mobile eco system and its services by taking into account the lessons learned from other/previous technologies. Concerted trial initiatives will lead to accelerated development cycles and early time to market.

The NGMN Alliance has established a Trial Working Group to accompany, guide and leverage industry activities and initiatives in the field of testing and validation of next generation candidate technologies.

Objectives of the NGMN Trial Working Group:

- Set up a framework to enable open collaboration between NGMN Partners and external trial initiatives;
- Consolidate and evaluate trial results for different next generation candidate technologies;
- Provide evidence of key technology capabilities in technical field trials and friendly customer trials; and
- Benchmark technologies against common NGMN requirements and recommendations (White Paper 3.0).

NGMN will not setup or execute trials on its own, but leverages existing trial initiatives of NGMN Partners or other industry forums based on an open and transparent collaboration framework. In a first stage, the NGMN Trial Group generates common trial requirements and test cases and provides these to the respective trial initiatives for consideration to get results in a consistent manner. In the second stage, the Trial Group accumulates specific trial results delivered from those initiatives and evaluates these trial results against the NGMN requirements and recommendations (see Figure 19).

Main deliverables of the NGMN Trial Working Group:

- Field Trial Requirements document (2 releases in 2008): describes test requirements to enable the verification of the NGMN White Paper requirements through field trials, including
  - Trial setup recommendations
  - End-to-end proof point descriptions
  - Reporting recommendations
- NGMN Approved Trial concept: encourage various trial activities to provide trial results to NGMN Trial WG
- Evaluation Methodology document
- Reports on proof-of-concept, technical field trials, and friendly customer trials.

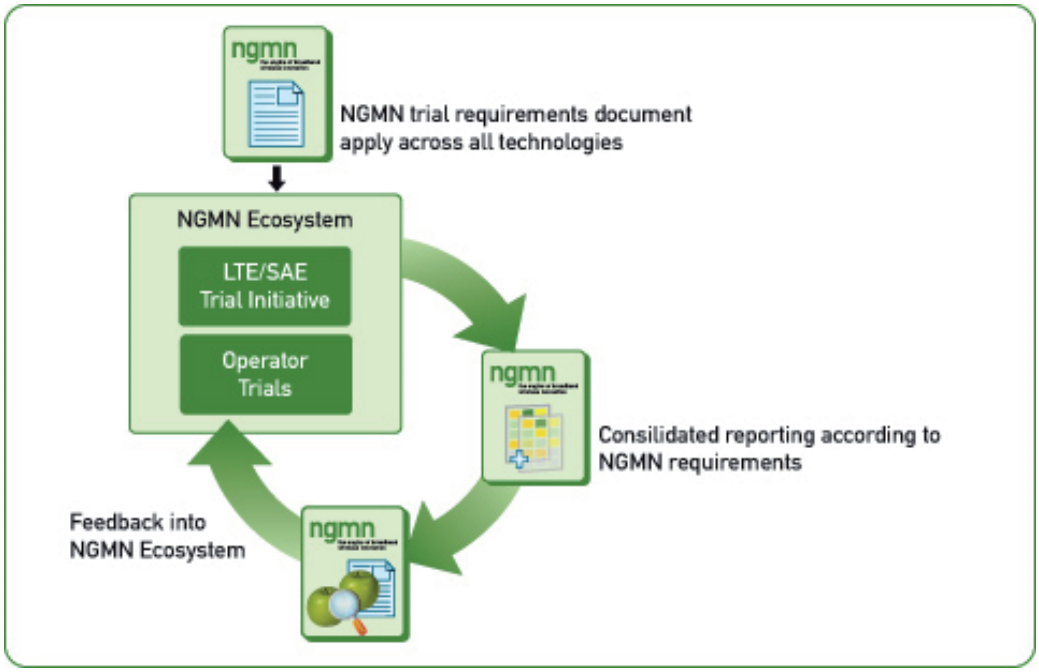



**Figure 20: NGMN Trial Working Group framework**

The NGMN Trial Working Group is currently in the phase of evaluating the trial results delivered by Trial initiatives such as LSTI and additional contributions made by NGMN member companies. The resulting report is targeted for Q1 2011. In addition the NGMN Trial Working Group has also enhanced the NGMN Field Trial Requirement document by including test cases for User Data Rates, see chapter 4.3, “Typical User Data Rate”. This to achieve, an application benchmark to verify customer experience with pure end-to-end approach and all protocol depending aspects was performed

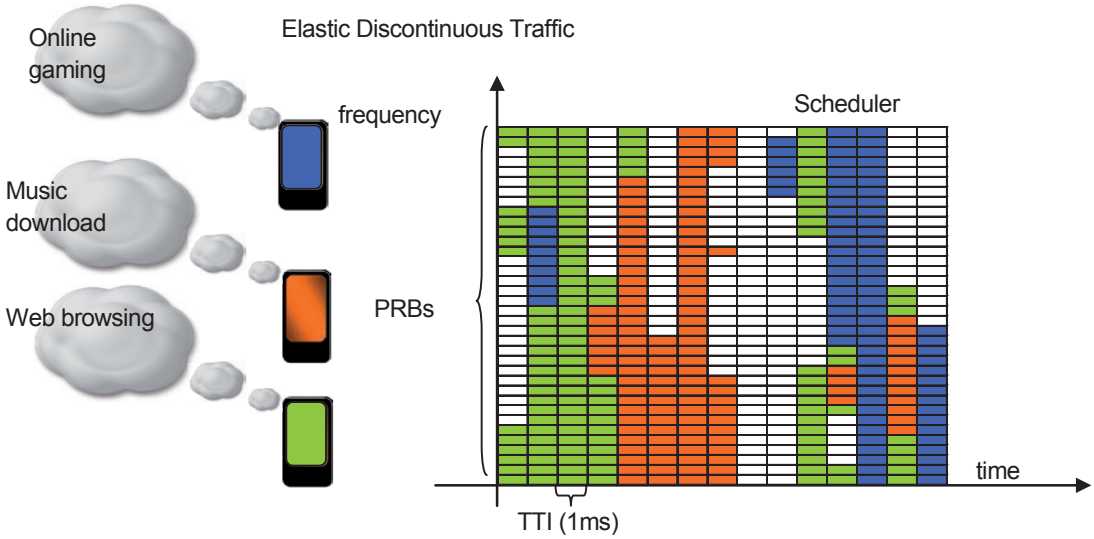



**Figure 21: Test case concept for User Data Rates**

The "NGMN Approved Trial" program was launched in 2008; it is aimed to encourage interested parties, such as operators or industry initiatives worldwide, to conduct their trials on next generation mobile technologies, by following a series of trial requirements defined by the NGMN Alliance. If the trial carried out is compliant to NGMN

Field Trial Requirements and all of the trial results are provided to NGMN for technology evaluation, including an open visit to NGMN operator members, then, the trial will be qualified as "NGMN Approved Trial".

The TD-LTE showcase network in Shanghai World Expo is setup and optimized by China Mobile, the world's largest mobile operator based on number of subscribers and network scale. Since the showcase network was built in 2009, China Mobile has run a comprehensive list of test cases to verify various performance criteria of TD-LTE technology. The tests include indoor/outdoor performance test, terminal IOT test, co-existence test with Wi-Fi, and service specific test. To further push the technology development and build industry confidence, China Mobile adopted NGMN's Field Trial Requirements into its set-up, shared its trial results/experiences with NGMN operators and applied for the NGMN Approved Trial compliance status. During the NGMN Shanghai meeting in June 2010, NGMN members visited the TD-LTE showcase network in World Expo and granted the first "NGMN Approved Trial" compliance status to China Mobile's Shanghai TD-LTE network. They appreciated China Mobile's dedication to the next generation wireless technology.

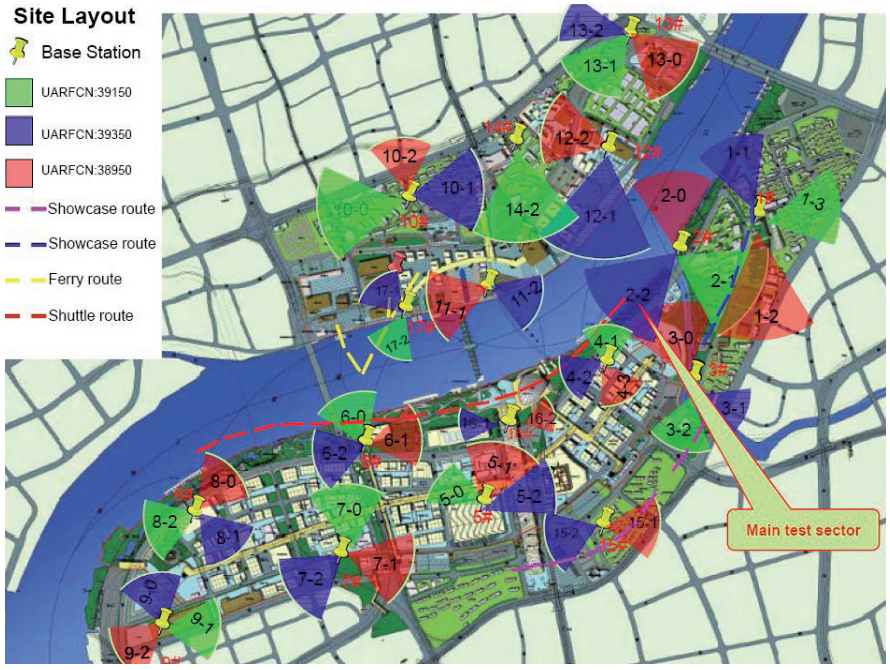



**Figure 22: The trial done at the Shanghai World Expo 2010 by China Mobile.**

The picture below gives an overview on the various activities and milestones that has been and will be performed within the Trial working group.

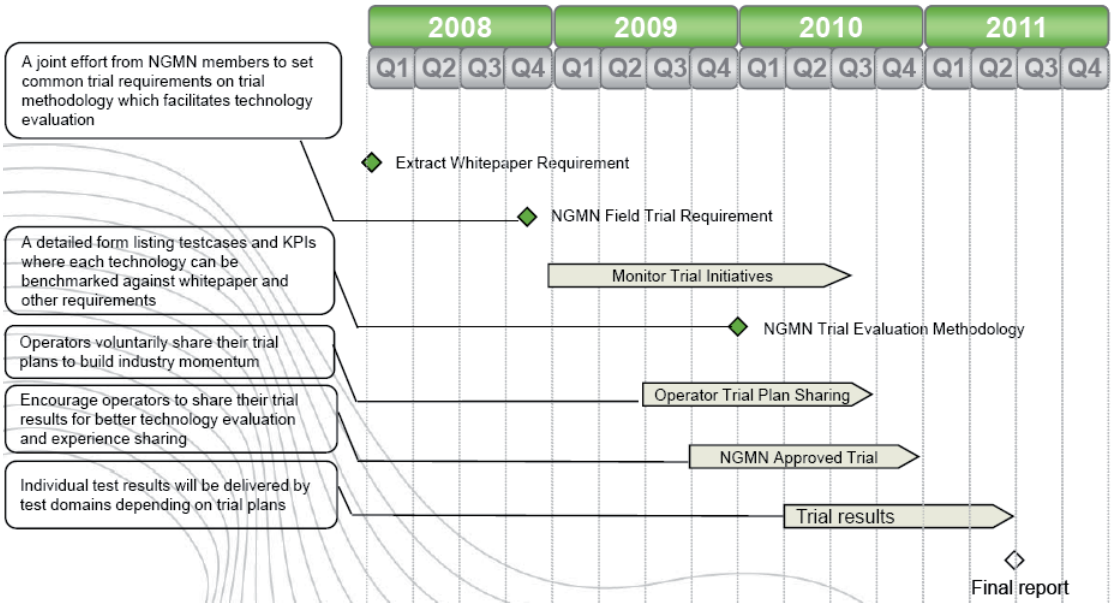



**Figure 23: Milestone schedule for the Trial Working Group 2007 - 2010 activities**

# 7 CONCLUSIONS

The NGMN Alliance has, through the works of technology evaluation, managed to decrease the complexity in selecting preferable technologies and indicated options for its partners and the industry as such to simplify the deployment of next generation mobile networks.

By addressing early the need for a well-established device certification regime for the next generation of mobile networks, many issues lsuch as test case availability and enhanced scope of certification of devices have been managed and high-lighted. In the area of devices, security has also been approached and recommendations have been outlined towards industry fora working with these aspects.

In the area of SON, a structure to create standardized solutions has helped the progress with the two deliverables NGMN has published. Major contributions have been made by NGMN partner companies to the 3GPP standardization. Operational efficiency will continue to be an important area to be addressed by NGMN in the coming years, and work has to be done on procedural efficiency, standardized O&M interfaces etc.

NGMN has aimed at achieving a full Multi-vendor capability and made major achievements for the S1 and X2 interfaces. However, there is still a significant need to ensure open standardized interfaces for the southbound interface of the Element Manager to the Network Element.

The backhaul requirements have been highlighted and addressed in a first deliverable from NGMN and additional work is ongoing to ensure that deployment scenarios, dimensioning, and other aspects for the next generation mobile network backhaul solution are addressed in a second deliverable, to be published in 2011.

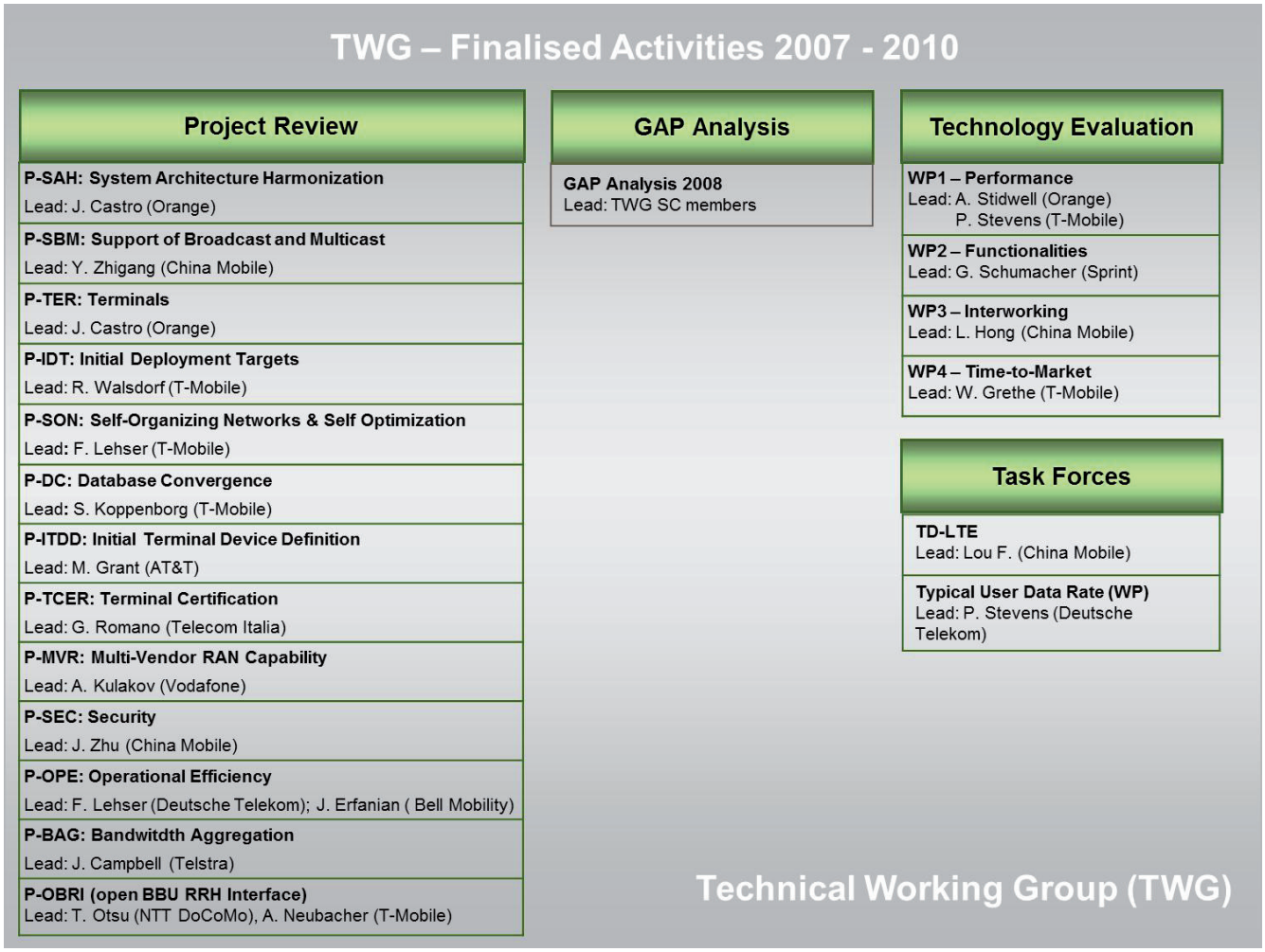
NGMN has established the work related to Open Interface between the Baseband Unit and Remote Radio Head and moved the specification to the ETSI Industry Specification Group ORI (Open Radio Equipment Interface). ORI aims to produce a full specification in Q1 2011 and NGMN will continue to follow this work with high interest in 2011.

The NGMN Trial Working Group has outlined the prioritized test cases for field trials and streamlined the mobile industry's efforts. In early 2011 the TWG will evaluate the results achieved by these recommended test cases based on the recommendations outlined in the NGMN White Paper 3.0.

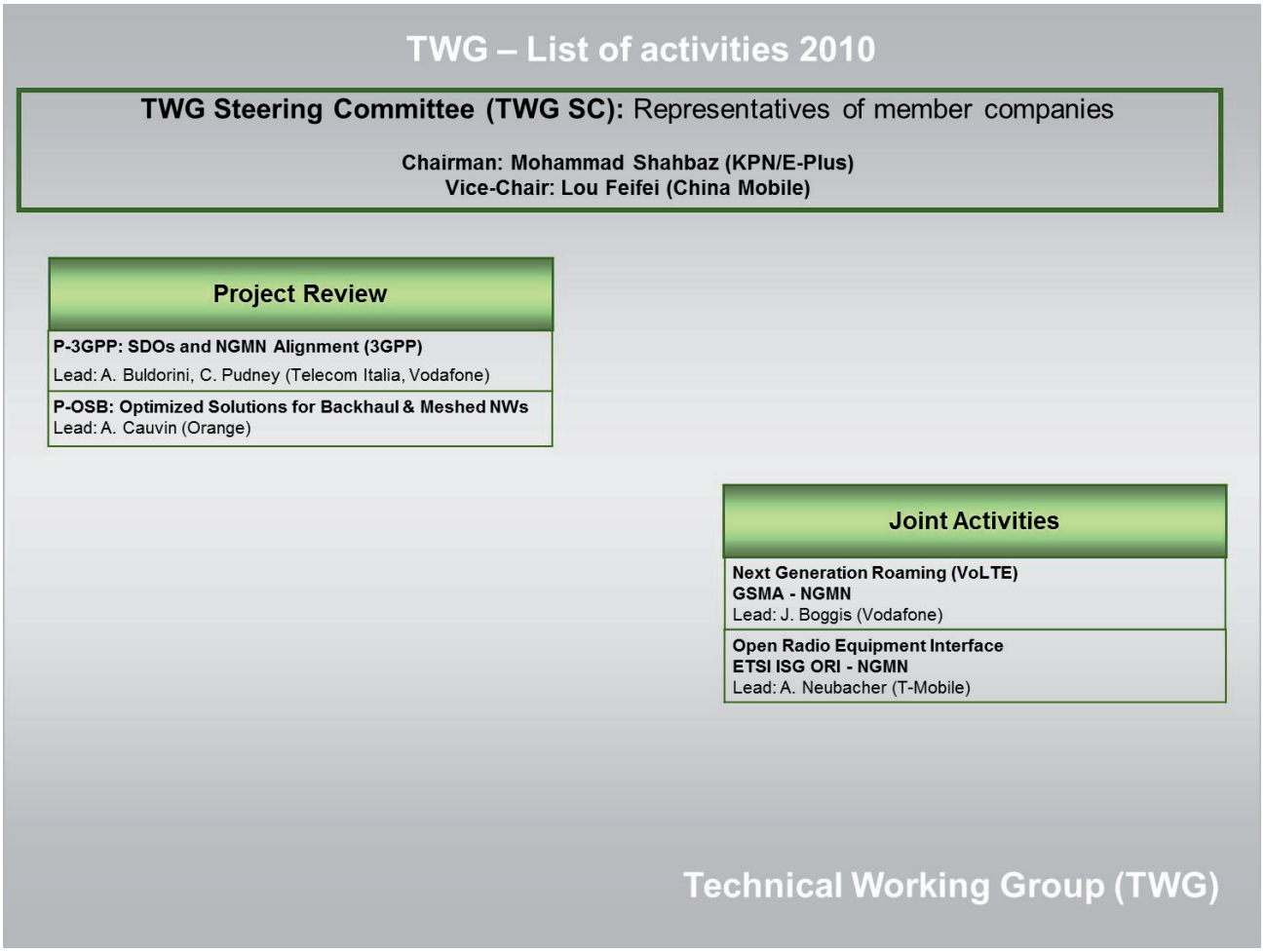
The NGMN Alliance will continue to work towards a fully-fledged realisation of the NGMN White Paper 3.0 functional and non-functional recommendations, and additional aspects that its members sees relevant for the launch and commercial mass deployment of the next generation of mobile networks.

# 8 APPENDIX

## 8.1 List of TWG SC Finalized Activities



## 8.2 List of TWG SC current Activities



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## 10 ABBREVIATIONS

| | |
|---|---|
| 3G | Generation |
| 3GPP | 3rd Generation Partnership Project |
| AGW | Access Gateway |
| BBF | Broadband Forum |
| BBIC | Base Band Integrated Circuits |
| BBU | Baseband Unit |
| BTS | Base Station Transceiver |
| C&M | Configuration & Management |
| CDMA | Code Division Multiple Access |
| CPRI | Common Public Radio Interface |
| CSFB | Circuit Switched Fall-Back |
| EDGE | Enhanced Data Rates for GSM Evolution |
| EPC | Evolved Packet Core |
| E-UTRA | Evolved Universal Terrestrial Radio Access |
| EVDO | Evolution Data Optimised |
| FCAPSI | Fault, Configuration, Accounting, Performance, Security Interface |
| FDD | Frequency Division Duplex |
| GCF | Global Certification Forum |
| GSM | Global System for Mobile Communications |
| GSMA | GSM Association |
| HeNB | Home eNB |
| HRPD / 1x RTT | High Rate Packet Data / 1 times 1.25 MHz channel Radio Transmission Technology |
| HSDPA | High Speed Downlink Packet Access |
| HSPA | High Speed Packet Access |
| HSUPA | High Speed Uplink Packet Access |
| IEEE | Institute of Electrical and Electronics Engineers |
| IMS | IP Multimedia Subsystem |
| IR | Implementation Recommendation |
| IRP | Integration Reference Point |
| ITDD | Initial Terminal Device Definition |
| LSTI | LTE SAE Trial Initiative |
| LTE | Long Term Evolution |
| MEF | Metro Ethernet Forum |
| MIMO | Multiple Input Multiple Output |
| MME | Mobility Management Entity |
| MNO | Mobile Network Operator |
| MSF | Multi-Service Forum |
| NGMN | Next Generation Mobile Networks |
| O&M | Operations & Maintenance |
| OBSAI | Open Base Station Architecture Initiative |
| OFDMA | Orthogonal Frequency-Division Multiple Access |
| OMA | Open Mobile Alliance |
| OMC | Operation and Maintenance Center |
| OMTP | Open Mobile Terminal Platform |
| ORI | Open Radio Equipment Interface |
| PCT | Performance Compliance Template |
| RE | Radio Equipment |
| REC | Radio Equipment Control |
| RFA | Ready For Acceptance |

| | |
|---|---|
| RFIC | Radio Frequency Integrated Circuits |
| RFU | Radio Frequency Unit |
| RRH | Remote Radio Head |
| RRM | Radio Resource Management |
| SAE | System Architecture Evolution |
| SC-FDMA | Single Carrier – Frequency Division Multiple Access |
| SDO | Standards Development Organisations |
| SFBC | Space Frequency Block Coding |
| SGW | Serving Gate Way |
| SINR | Signal to Interference and Noise Ratio |
| SMS | Short Message Service |
| SON | Self Organizing Network |
| TDD | Time Division Duplex |
| TWG SC | Technical Working Group Steering Committee |
| UMTS | Universal Mobile Telecommunications System |
| UTRA | Universal Terrestrial Radio Access |
| WiMAX | Worldwide Interoperability for Microwave Access |