



P.15.02.10 Final Project Report

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Abstract

This deliverable comprises the P.15.02.10 Final Project Report. The project has demonstrated the suitability of PENS (Pan-European Network Service) as the backbone ground/ground communication infrastructure.

To achieve the above, four main technical areas were addressed within the project:

- Evaluation of end-to-end performances in PENS
- Security Framework
- Verification of IP Multicast applications
- Verification of VoIP for ATM

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Publishable summary

A Pan-European IP Network is a fundamental technical enabler to support the new SESAR concepts. Performances and security of such a network are key issues that have been assessed throughout this project in order to define the specific requirements of the various network elements.

The project aimed at defining and verifying a terrestrial communications infrastructure appropriate for ATM ground/ground communication applications, being capable of supporting the existing services (i.e. voice, messaging) and addressing the new concepts to be developed in SESAR such as SWIM (System Wide Information Management) services.

To achieve this goal, P.15.02.10 work has been divided into the following main technical areas:

- **EVALUATION OF END-TO-END PERFORMANCES IN PENS:** supported by projects tasks T1, T2 and T3. PENS activities included the analysis of requirements and applications to be PENS users, the definition and verification of a methodology for PENS testing, and finally the integration and testing of PENS performances. Within this activity, an important milestone was the creation of the SESAR VPN that was approved by the PENS Services Steering Group (PSSG), the steering body composed by several European ANSPs and EUROCONTROL. Thus, the SESAR VPN was created as an additional VPN for testing purposes, in addition to the existing ANSP Backbone. Hereafter the SESAR VPN was deployed among the selected P.15.02.10 sites, supporting the different exercises during the whole project. The SESAR-VPN can be considered the closest approach from a technical point of view to the future operational PENS. In this sense, the actual SESAR VPN has been assumed to be representative of an ANSP operational network.

After the initial deployment of the SESAR VPN, further capabilities such as IPv6 support, IPv4 Multicast Pilot, or additional QoS features to support Voice over IP requirements were requested and implemented by the PEN Service Provider, and validated within the different technical activities. During this activity, some recommendations in foresight for the next operational phase were also raised for consideration of the PENS Management Unit (PMU), that provides administrative support of PENS, and to the PENS User Group (PUG), the technical development group of PENS.

- **SECURITY POLICY, PROCEDURES AND ARCHITECTURE:** supported by project tasks T4, T5 and T6. The security activities included the SWIM Backbone Security Risk Assessment, the development and testing of the Security System model, and the development of the final SWIM backbone security management documents. The security activities were aligned with other security related activities, in particular with projects addressing SWIM security.

As outcome of the security tasks, the final SWIM backbone security management documents have been distributed as input to the relevant stakeholders of PENS, in particular to the PSSG and PUG groups.

- **VERIFICATION OF IP MULTICAST APPLICATIONS:** supported by project tasks T7, T8 and T9. Within these activities, the project performed the research and development activities, technical assessments and testing necessary to verify that IP multicast can be provided in suitable manner by the network on an end to end basis (ANSPs networks interconnected through PENS). The multicast activities focused on the IP Multicast requirements analysis and test scenarios definition, the implementation of IP multicast testbeds and the verification of IP Multicast capabilities on PENS.

Within this area, an important milestone was the design and implementation of the IPv4 Multicast Pilot connecting a selected number of PENS sites, a joint work of the PEN Service Provider and the project team. The multicast tests were focused on verification of the IP Multicast Pilot performances, and the demonstration of the suitability of PENS for multicast data distribution. In particular, live radar data exchange between several nodes was demonstrated within the IP Multicast tests.

- **VERIFICATION OF VOIP FOR ATM:** supported by project tasks T10, T11 and T12. The VoIP activities addressed the analysis of ATM VoIP communications within PENS/ANSPs networks. The activities included the analysis of ATM VoIP standards, the identification of new service elements to support voice communications over the PENS network, the development of verification plans and test scenarios, the preparation of test environment including ATM VoIP equipment, and the execution of large-scale field trials. The VoIP activities were also coordinated with standardization working groups related to VoIP for ATM, such as EUROCONTROL VOTE and EUROCAE WG67.

EUROCAE WG67 standards and EUROCONTROL Test Case Specification were taken as reference for defining and conducting the validation tests over PENS.

Within these activities, the project requested an upgrade of the SESAR VPN to the so called Platinum Service, an extended service offered by the service provider aiming to improve QoS guarantees. Other additional features, such as the implementation of a separated class of service to support voice signalling, were also requested and implemented for the project duration to meet QoS requirements stated in EUROCAE ED138.

Voice equipment provided by the different manufacturers participating in P.15.02.10, that included radio and telephony VCS equipment, were compliant with the latest EUROCAE ED-137B standard, thus interoperability was guaranteed.

New service elements, such as Climax Dynamic Delay Compensation defined within EUROCONTROL VOTE and adopted by EUROCAE WG67 was also implemented and validated by this activity.

End-to-end performance for ground voice communication was validated against EUROCAE ED-136 and ED-138 requirements.

Finally, within Phase II of the large-scale field trials, the first ATM VoIP IPv6 validation tests over PENS were successfully conducted.

The overall P.15.02.10 structure is depicted in the following figure:

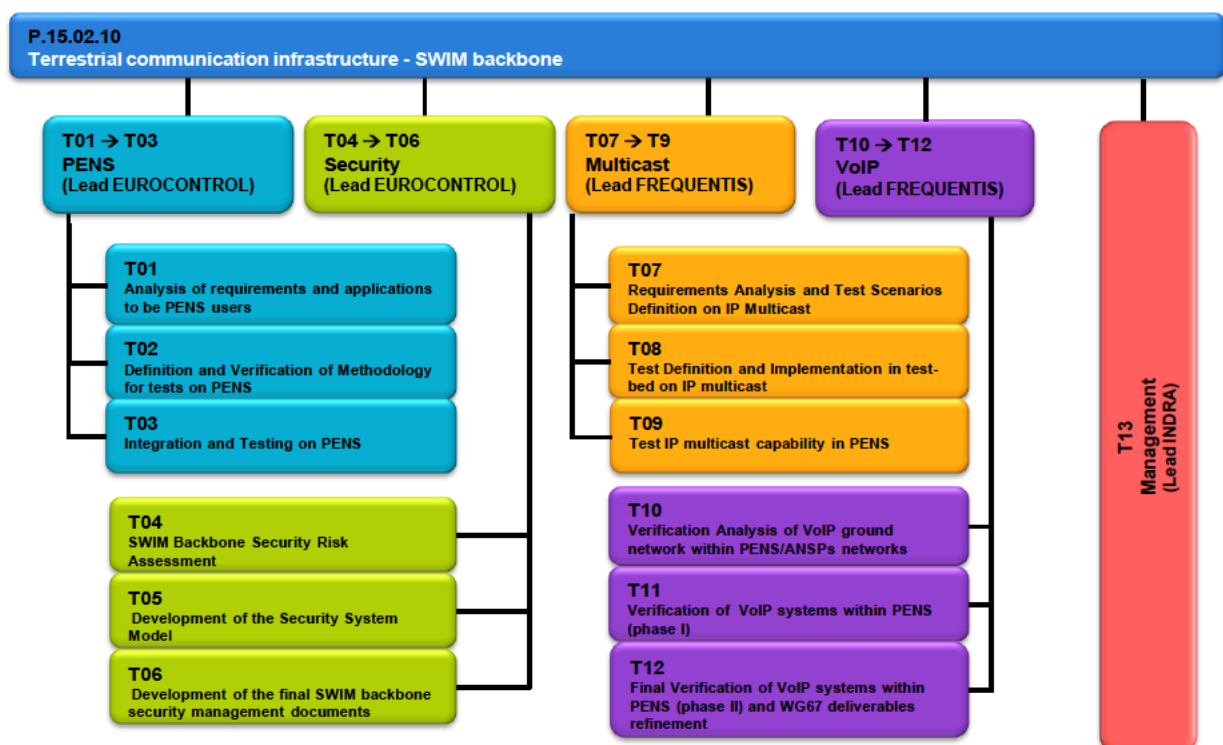


Figure 1: P.15.02.10 Working Areas

During the project life, the following coordination took place with other SESAR projects and external working groups:

- As interface between the SESAR community and the PENS community, P.15.02.10 had a close coordination with the PMU and the PENS service provider during the SESAR VPN deployment phase and the different test campaigns, identifying and reporting any issue related to the network, and requesting the appropriate modifications to achieve the project goals. There was also coordination with the PUG and PSSG, that was achieved through EUROCONTROL as manager of the SESAR VPN contract and interface of the P.15.02.10 project to the PENS community.
- With regard to the multicast tasks, there was interaction with SWIM projects by collecting the available requirements applicable to the PENS network and defining potential solutions to support the SWIM concept. Being those SWIM requirements still under development, new requirements that raised after the finalization of the IP Multicast activities, deriving into a need of redesign of the initial IP Multicast pilot, could not be addressed by P.15.02.10. A specific PENS Multicast task force was created, also participated by P15.02.10 representatives, to collect the outcome of the P.15.02.10 activities and to continue the work beyond the scope of P.15.02.10 to identify multicast scenarios and requirements to support mid and long term SWIM solution.
- The security tasks were coordinated with other SESAR projects, in particular with P.14.02.02 and WP16. Initial scope of the project was reviewed and aligned with P.14.02.02 to avoid effort duplication. In addition, due to the approach taken and the nature of the PENS security risk assessment, the outcome of P.15.02.10 project is expected to be a potential input to the PSSG. Any discussion on the extension of PENS to other aeronautical stakeholders shall take due consideration of the recommendations produced by the security activities in P15.02.10. In addition, the Security Risk Assessment cannot be considered as a closed task, but it is a living process that will require several iterations and continuous updates with the evolution of PENS. Further analysis beyond the scope of P.15.02.10 will be required to reassess the SRA, considering the new conditions resulting from the expansion of PENS.
- For the VoIP activities, the project received input documents from EUROCONTROL VOTE and EUROCAE WG67 groups, to define the validation scenarios, the specification of the test cases and to define the acceptance criteria of the validation tests during different tests campaigns. EUROCAE standards were also followed to guarantee the interoperability of the ATM VoIP solutions provided by the different P15.02.10 partners. P.15.02.10 contributed to VOTE meetings by providing updates on the evolution of P15.02.10 VoIP activities. The outcome of P.15.02.10 validation of ATM VoIP over PENS, including some refinement and recommendations on EUROCAE deliverables, will be an input to EUROCAE WG67.

As a conclusion, the P.15.02.10 activities provide sufficient and re-useable inputs to other SESAR projects and external working groups. From the large number of tests conducted, it can be concluded that PENS performances should be suitable from the technical perspective. However, the validation activities also identified a few aspects that might need to be further investigated and improved before becoming the future SWIM backbone and before entering into a future operational deployment, highlighting that ATM in general is a safety critical environment and therefore safety aspects cannot be addressed in the same way as in general purpose networks.

The SESAR 15.02.10 project team was composed by four ANSPs (AENA, DFS, DSN and ENAV), EUROCONTROL and three industry partners (INDRA, FREQUENTIS and SELEX ES).

Acronyms

Term	Definition
AMHS	Aeronautical Message Handling System
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
BGP	Border Gateway Protocol
E-OCVM	European Operational Concept Validation Methodology
EUROCAE	European Organization for Civil Aviation Equipment
FMTF	Flight Message Transfer Protocol
ICAO	International Civil Aviation Organization
IP	Internet Protocol
LARA	Local And Regional Airspace Management
PCG	Programme Control Group
PENS	Pan-European Network Service
PMU	PENS Management Unit
PSSG	PENS Services Steering Group
PUG	PENS Users Group
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SWIM	System Wide Information Management
VCS	Voice Communications System
VoIP	Voice over IP
VOTE	VoIP in ATM implementation and Transition Expert-group
VPN	Virtual Private Network
WAN	Wide Area Network
WG	Working Group

1 Final Project Report

1.1 Project progress and contribution

The activities addressed by P15.02.10 contributed to the following system Enablers as captured in the ATM MasterPlan¹:

EN Code	EN Title	P15.02.10 activities /contributions	Maturity ² before project	Maturity ² after project
CTE-C8	Digital voice/VoIP for ground telephony	Assessment of the performance of Digital voice/VoIP (ED137B Vol2) for Ground Telephony over PENS	V2	V3 / V4
CTE-C9	VoIP for ground segment of Air-Ground voice	Assessment of the performance of Digital voice/VoIP (ED137B Vol1) for ground segment of Air-Ground voice over PENS.	V2	V3 / V4
CTE-C11	Pan-European network service (PENS), in support of the European ANSPs needs, for information exchange (first set of users and of communication network services)	PENS Security Policy basis Assessment of AMHS, FMTP, Surveillance data exchange, VoIP (radio and telephony) across PENS	V2	V3
MIL-0502	Support MIL-0501 with ground-ground COM interface for interconnection of military systems to PENS	Assessment of LARA across PENS	V2	V3

Table 1 - List of enablers and project contribution

Project 15.02.10 addressed the suitability of PENS as a key technical enabler for the SESAR concept of operation providing a common IP-based communications infrastructure with enhanced performance and security, capable of integrating all of the ATM data and voice communication services that will make up the future SWIM.

The IP end-to-end baseline infrastructure including the interconnection of the different network entities and services in the ATM framework through the PENS backbone, shall comply with the performances verified through this project in order to support data exchange applications (e.g. VoIP and IP multicast), the future SWIM applications, and the Local And Regional Airspace Management (LARA) Systems from the military side.

¹ Data Set 11 (October 2013) is the latest publicly available at the time of writing this report,

² The E-OCVM cycle is applicable to the validation of operational concepts and the assessment of its maturity. However, the E-OCVM cycle can be extended to technology verification activities, by making some analogy with Technological Readiness Level. The last two columns of Table 1 provide an indicative estimation of the project contributions towards the maturity of enablers considered in the project, supported by performance evidences provided in the P.15.02.10 project deliverables.

This project contributed to the performance specifications of a robust end to end network structured around the PENS backbone, capable of integrating all the ATM data and voice communication services including the SWIM specific services and the identified military services (e.g., LARA Application).

1.2 Project achievements

A summary of the project achievements is presented below:

- In terms of performance, the project demonstrated the suitability of PENS (Pan-European Network Service) as candidate for the future IP backbone for ground/ground communication infrastructure supporting the future ATM services. However, some issues identified by the Project team need to be addressed beyond P.15.02.10 and before the deployment phase.
- Security research and development work established the basis for an appropriate PENS Security Policy that will address ATM requirements. This research included a Security Risk Assessment, the setup of relevant test beds, execution of vulnerability tests over PENS and the development of the security model documents. The work will need to be continued beyond the project scope.
- In absence of an existing IP Multicast infrastructure in PENS, the project defined the requirements for a basic IPv4 multicast pilot based on the existing information. On this IPv4 Multicast pilot, the project successfully performed verification tests for IP multicast for Surveillance Data Distribution, demonstrating the benefits of multicast technology for data distribution.
- The project successfully performed verification of VoIP applications, boosting the implementation of VoIP within the ATM environment in a near future. EUROCAE standards and EUROCONTROL test procedures and recommendations were taken as reference and as acceptance criteria for defining and conducting the validation tests, obtaining excellent results. In addition, the first ATM VoIP IPv6 validation tests over PENS were successfully conducted by the Project team.

A summary of the issues identified by the project activities is presented below:

Domain	Description of identified issue	Treatment Actions and Resolution
PENS	Some issues were identified related to PENS itself (such as configuration issues, site availability, service outage, network monitoring)	Issues formally transferred to PSSG/PUG to further address the issues identified
	The SESAR VPN was arranged for the support of P.15.02.10 and would not be available beyond the finalization of the project	The issue was raised to the PCG and members (A6 and ECTL) have taken the necessary action to assure to continued availability of the SESAR VPN
SECURITY	Coordination with SWIM security required	Coordination with 14.02.02 and WP16 took place. P.14.02.02 to include P.15.02.10 outcome
	Security issue found affecting IP Routing control traffic (BGP traffic vs. Data traffic)	Issue formally transferred to PSSG/PUG to further address the issues identified
	Security management documents need to be addressed by the PENS managers	Security documentation provided to PSSG as input guidance to establish a PENS security policy
MULTICAST	Multicast activity need to be further developed beyond the scope of P.15.02.10. Only IPv4	Ongoing PENS Multicast Task Force, is expected to propose further multicast

	multicast pilot based on Multicast SSM model was provided to the project	solutions to support the long term SWIM concept
VOIP	Specific VoIP issues were found, in particular related to RTP voice jitter in one of the SESAR VPN sites	Issue formally transferred to PSSG/PUG to further address the issues identified
	Recommendations to EUROCAE WG67 deliverables	Recommendations provided to EUROCAE

Table 2 - List of Issues indentified by Project activities

1.3 Project deliverables

A summary of the project deliverables is presented in the table below:

Del. code	Del.Name	Description	Assessment Decision
D000	Final Progress status report	The deliverable (this document) comprises the P.15.02.10 Final Project Report	No reservation
D01	Report on final requirements and applications to be PENS users	The deliverable comprises the identification of the current and future ATC applications that will become PENS users, as well as an analysis of the communication requirements of ATC applications that will become PENS users. In addition to this, the parameters to be validated were identified	No reservation
D02	Report on Methodology and laboratory Verification	The deliverable defines a methodology for tests, verification scenarios for laboratory tests and field trials, and proves the verification of the chosen methodology in the laboratory	No reservation
D03	Conclusions report on PENS suitability for IP applications	The deliverable contains the requirements and technical specifications of PENS VPN functions, based on the inputs from analysis in WA7 and WA10. Moreover, the main contents of this document are the conclusions on PENS suitability based on the tests outputs, including gaps and/or constrains identification, addressing a re-design of the infrastructure	No reservation (P)
D04	SWIM Backbone Security Risk Assessment	The deliverable is comprised of a gap-analysis report including risk assessment methodology. Additionally, the deliverable contains a PENS Security Risk Assessment, taking into account the civil/military and inter-regional interoperability, addressing different applications: FMTP, AMHS, VoIP, IP multicast, etc.	No reservation (P)
D05	Security System Specification	The deliverable includes a description of the Security Mechanism Model and a vulnerability test specification taking into account civil/military specification, and reporting on the tests bed and tools performed for vulnerability and civil/military interoperability	No reservation (P)

D06	SWIM backbone security management	The deliverable comprises a final report taking into account the Security Policy and Architecture agreed and design among the stakeholders, as well as a Security Risk Assessment for all the applications to be considered on the SWIM backbone	No reservation
D07	Requirements Analysis and Identification of Modifications required for IP Multicast	The deliverable includes a specification of application requiring IP multicast and required modifications to the existing PENS infrastructure to support them. Additionally, test scenarios are defined	No reservation
D08	First Test Report on multicast-functionality	The deliverable contains a report on first test bed performed on IP multicast capability reflecting potential constraints and caveats associated to the infrastructure.	No reservation
D09	Guidelines for IP multicast applications via PENS	The deliverable comprises the guidelines for IP multicast applications via PENS, and the identification of issues taking into account the results achieved in the previous WA	No reservation (P)
D10	Verification Analysis of VoIP ground network within PENS_ANSPs networks	The deliverable defines the verification scenarios and test specifications (voice traffic patterns, loading and acceptance metrics) for laboratory test. Moreover, a detailed verification plan for laboratory tests and field trials using the PENS/ANSPs infrastructure is performed	No reservation
D11	Draft Report on Verification of VoIP	The deliverable contains a draft report on verification of VoIP G/G Technology for G/G Communication and ground segment of A/G Communications Phase I, which includes laboratory tests and PENS IPv4 infrastructure	No reservation (P)
D12	Report on Verification of VoIP Technology for G_G & A_G Communications	The deliverable produces a report on Verification of VoIP G/G Technology for G/G & A/G Communications (inclusive proposed amendments to G/G and A/G communication standards), Phase II, which includes IPv6 PENS infrastructure. In addition to this, a report on the coordination activities carried out with different international bodies (EUROCAE, ICAO) is included	No reservation

Table 3 - List of Project Deliverables

1.4 Contribution to standardization

With regard to standardization, P.15.02.10 was closely related to the EUROCONTROL VOTE and EUROCAE WG67 on VoIP for ATM. Also some coordination with ICAO took place.

The table below summarizes the different contributions to standardization:

Domain	Description
Security	Deliverables D05, D05, and D06 were identified as relevant inputs to ICAO WG-I
Multicast	Multicast deliverables identified as potential input for development of IPS Implementation guidance in ICAO DOC 9896 ed 3 currently under development
VoIP	Outcome of WA12 identified as relevant input to EUROCONTROL VOTE and EUROCAE WG67 groups. D12 also includes recommendations and amendments to WG67 deliverables.

Table 4 - Standardization

1.5 Project Conclusions and Recommendations

The analysis of the extensive number of tests executed in the project shows overall positive results and outcome, and has enabled the project to reach a number of conclusion and recommendations. A summary of the project main conclusions and recommendations is presented below:

- In terms of performance, the project demonstrated that PENS (Pan-European Network Service) can be suitable as the future IP backbone for ground/ground communication infrastructure supporting future ATM services.
- The verification activities conducted under P.15.02.10 covered an extensive number of test scenarios, including network performance tests, security vulnerability tests, IP Multicast Tests, and VoIP tests and their analysis show overall positive performances.
- In some cases some incidents were identified when analysing the test results. Some of them were caused by local issues, whereas some issues require further investigation. These have been properly identified and raised with the appropriate PENS groups.
- Proper capacity planning is one of the most important factors that the Service Provider has to consider, provisioning sufficient network bandwidth to support priority traffic, and guaranteeing that the priority class has a certain percentage of the total bandwidth.
- There is need to continue monitoring the service levels provided after the completion of a network solution deployment and to appropriately react on any potential network incident detected.
- A well-defined and coordinated PENS CM (Configuration Management) between the PENS Network Service Provider and the PENS Users is highly recommended to be in place from the beginning of any operational usage of PENS. This will allow handling changes systematically saving time and efforts and it will also improve the coordination between the PENS Users and the PENS Service Provider when new changes on the network are requested, implemented, and/or tested.
- Periodic adjustments and tuning of QoS policies used are recommended to achieve a successful QoS network deployment and operations.
- The heterogeneity of PENS components (e.g., virtual circuits over different access technologies) may become a critical issue when dealing with real time traffic such as Voice over IP since they are susceptible to increased latency when traversing low-speed WAN circuits.

- The QoS offered to the end user should be transparent to the underlying L2 technology. It is proposed that the Service Provider is responsible to implement appropriate mechanisms in each site to guarantee the required levels of QoS for all sites.
- Some identified issues (described in deliverables D03, D06, D09 and D12) need to be further investigated by the PENS Service Provider and should be addressed before deploying critical operational applications over PENS. These issues have been communicated to the PENS PSSG group, as the most appropriate forum to address them.
- It is highlighted that ATM in general is a safety critical environment and therefore safety aspects cannot be addressed in the same way as a general purpose network.

2 References

Reference to main documentation, delete if not required

- [1] [SESAR Programme Management Plan, Edition 03.00.00](#)
- [2] [European ATM Master Plan, Edition 2](#)
- [3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012
- [4] Latest Project baseline (Edition date 04/09/2012)
- [5] P.15.02.10-D01_00.02.00 Report on final requirements and applications to be PENS users
- [6] P.15.02.10-D02_00.02.00 Report on Test Methodology and Laboratory Verification
- [7] P.15.02.10-D03_00.01.00 Report on PENS suitability for IP applications
- [8] P.15.02.10-D04_00.01.00 SWIM Backbone Security Risk Assessment
- [9] P.15.02.10-D05_00.01.00 SWIM Backbone Security System Model
- [10] P.15.02.10-D06_00.02.00 SWIM Backbone Security Management
- [11] P.15.02.10-D07_00.02.00 Requirements analysis and test scenario definition on IP multicast
- [12] P.15.02.10-D08_00.01.00 Test Definition and Implementation in test-bed on IP multicast
- [13] P.15.02.10-D09_00.01.00 Guidelines for IP multicast applications via PENS
- [14] P.15.02.10-D10_00.01.00 Verification Analysis of VoIP ground network within PENS/ANSPs networks
- [15] P.15.02.10-D11_00.01.00 Interim Report on Verification of VoIP Technology for G/G & A/G Communications
- [16] P.15.02.10-D12_00.01.00 Report on Verification of VoIP Technology for G/G & A/G Communications

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