Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems

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Abstract

This deliverable summarises the standardisation and the exploitation activities of the 5G-Xcast project. Standardisation activities have been described in categories of 3GPP Work Item proposals and Study Item proposals, contributions to 3GPP Technical Specification Groups and Working Groups, contributions to DVB Technical Module, and IETF Internet Draft. The contributed documents to 3GPP, DVB and IETF standardisation are listed. The innovation results are also summarised including patent filing.

Keywords

5G-PPP Phase 2, dissemination, standardisation, 3GPP standard, 3GPP Work Item, 3GPP Study Item, exploitation, innovation.

Executive Summary

This deliverable describes the standardisation and exploitation activities carried out within the 5G-Xcast project. 5G-Xcast partners are involved in various Standard Developing Organisations (SDOs) such as 3GPP, DVB, ETSI, ATSC and ITU. Leveraging on the strong position in different SDOs, 5G-Xcast partners disseminate the project results to other industry and regulation stakeholders.

The project has achieved its goal of standard contribution by greatly exceeding the initially planned target. The initial target of standard contributions was 15 and 123 contributions have been submitted to various SDOs. These contributions fall in various categories: 3GPP Study Item (SI) and Work Item (WI) proposals, 3GPP Temporary Document (TDoc) contributions, DVB working group standard contributions, and an IETF internet draft.

3GPP is a prominent SDO working on the development of complete 5G solutions to be submitted as an IMT-2020 candidate to ITU. For each 5G topic to be standardised on there needs to be an SI or a WI to be set up a priori. 5G-Xcast partners have been working to propose SIs for 5G to support multicast/broadcast in Rel-15 and Rel-16. For Rel-15 there was no broadcast support. For Rel-16, the offline discussion on the reflector led to the creation of two SI proposals: an SI on 5G Terrestrial Broadcast (RP-180672) and an SI on NR mixed mode broadcast/multicast (RP-180669). The SI terrestrial broadcast was supported by many 5G-Xcast partners (BBC, BT, EBU, IRT, Nomor. Nokia, One2many and Samsung) and officially approved by 3GPP. The SI Mixed Mode Broadcast was not approved due to the lack of time units but would be considered in the future. The 5G terrestrial broadcast SI represents a good opportunity for 5G-Xcast partners to submit their views discussed within the project to the larger 3GPP community.

5G-Xcast partners are also very active in DVB. There is a new working group focused on DVB WIB (Wideband reuse 1). This proposed concept is about a low order modulation coupled with a frequency reuse factor of 1 instead of the classical reuse factor of 5 or 7. The loss of capacity from the lower modulation mode is compensated by using a wider bandwidth channel. 5G-Xcast partners contributed to the study of coverage and simulations of receiver performance in DVB-WiB systems.

Exploitation is another dimension of the project where it is sought to maximise the benefits that partners can get from the project. This is done in a form of leveraging on the 5G-Xcast features to increase the partners' competitiveness and improve their products and services relating to media and broadcast. 5G-Xcast partners have exploited the project results in various ways according to their nature, operational activity and size. Through this, partners enhance their products, influence SDOs to adopt new features, and increase knowledge and know-how within their organisation.

5G-Xcast partners also filed patents which show the project innovation. The Intelligent Property Rights and benefits they bring in are much meaningful to the SME partners' growth.

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List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
5G	5th Generation
ADSL	Asymmetric Digital Subscriber Line
AL-FEC	Forward Error Correction at Application Layer
ASN	Abstract Syntax Notation
ATSC	Advanced Television Systems Committee
BM-SC	Broadcast-Multicast Service Centre
CAGR	Compound annual growth rate
CAS	Cell acquisition subframe
CB	Cell Broadcast
CDN	Content Distribution Network
CoAP	Constrained Application Protocol
CR	Change Request
CT	Core Network and Terminals
DASH	Dynamic Adaptive Streaming over HTTP
DTG	Digital TV Group
DVB	Digital Video Broadcasting
DVB-T	Digital Video Broadcasting – Terrestrial
DVB-T2	Digital Video Broadcasting – Second Generation Terrestrial
E-UTRA	Evolved Universal Terrestrial Radio Access
EC	European Commission
ETSI	European Telecommunications Standards Institute
FEC	Forward Error Correction
FHD	Full High Definition
FDT	File Delivery Table
FOBTV	Future of Broadcast Television
FRASE	FEC and ROHC activation for GCSE over MBMS
GCSE	Group Communication System Enabler
GW	Gateway
HbbTV	Hybrid Broadcast Broadband TV
HD	High Definition
HPHT	High Power High Tower
IETF	Internet Engineering Task Force
IoT	Internet of Things
IPR	Intellectual Property Right
ITU	International Telecommunication Union
IWF	Inter Working Function
LTE	Long Term Evolution
MBMS	Multimedia Broadcast Multicast Service
MFN	Multi-frequency network
MooD	Multicast/Broadcast operation on Demand
NEM	New European Media
NR	New Radio
OTT	Over The Top
pCR	Pseudo Change Request
PoC	Proof of Concept
PWS	Public Warning System
QAM	Quadrature Amplitude Modulation
QUIC	Quick UDP Internet Connections
RAN	Radio Access Network
ROHC	Robust Header Compression
SA	Service and System Aspects
SAND	Server and Network Assisted DASH
SDK	Software development kit
SDO	Standard Developing Organisation
SerInter	Service Interactivity
SFN	Single frequency network

SI	Study Item
SID	Study Item Description
SME	Small and Medium-sized Enterprise
Tdoc	Temporary Document
TM-WIB	Technical Module – Wideband
TR	Technical Report
TX	Transmission
TS	Technical Specification
TSG	Technical Specification Group
UHD	Ultra High Definition
UHF	Ultra High Frequency
V2X	Vehicular-to-Everything
WG	Working Group
WI	Work Item
WID	Work Item Description
WiB	Wideband

1 Introduction

This deliverable summarises the standardisation and exploitation activities in 5G-Xcast. The project has facilitated the interaction between the consortium and other industry partners in order to maximise the impact on Standard Developing Organisations (SDOs). SDOs are important for 5G-Xcast to spread the technical results of the project so as to have an impact on the on-going standardisation effort in the field of 5G wireless technologies. The project partners have very strong presence in European and global SDOs as shown in the table below.

Table 1: Project partners membership in different SDOs.

	3GPP	ATSC	DTG	DVB	ETSI	FOBTV	HbbTV	ITU
UPV								
NOK								
BBC								
BT								
BPK								
BLB								
EXP								
FS								
IRT								
LU								
NOM								
O2M								
SEUK								
TIM								
TUAS								
EBU								
UNIS								

A table summarising the targets of the project for different standardisation and exploitation activities, as well as the objectives reached so far, is given below.

Table 2: Project target and current number of standardisation activities.

Activity		Results	Target
Standard contributions total		171	15
Breakdown	3GPP SI/WI proposals	30	
	3GPP other Tdocs	133	
	DVB	7	
	IETF	1	

As shown in Table 2, the target related to the number of standard contributions has been very well achieved. The details of each contribution are listed in Chapter 2.

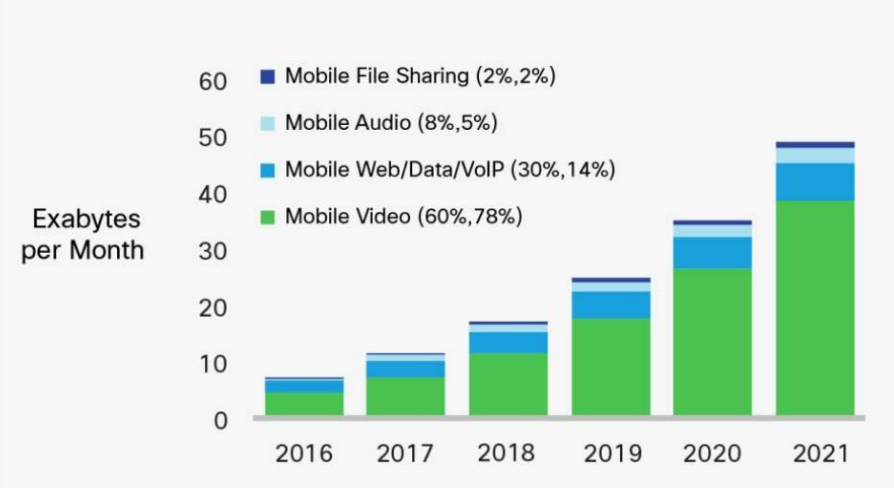
Chapter 3 elaborates the exploitation results and Chapter 4 gives the innovation outcome.

2 Standardisation activities

2.1 3GPP Study Item (SI) and Work Item (WI) Proposals

Mobile devices such as smart phones and tablets have become major tools to be entertained with various multimedia contents rather than traditional TV and set-top box. This trend was already evident with the widespread deployment of LTE cellular networks. LTE has enabled people to enjoy HD multimedia contents such as YouTube with their mobile devices.

Recently, UHD/4K (3840×2160 ~ 4,096×2,160) and 8K (7,680×4,320) contents are getting popular over HD/FHD (full HD). The Super Bowl LI, which is the championship game of American football on 5 February 2017, was shot in 4K and 8K with 360 degree view and broadcasted through TV and Internet. Also, Fox Sports delivered augmented reality with informative graphics with 38 UHD (ultra HD) cameras all over the stadium. The image/video quality of multimedia contents has been improved thanks to the advancement in image processing, storage, and other hardware implementation. Cisco expects the video traffic in mobile networks to grow by a solid 54% Compound annual growth rate (CAGR) between 2016 and 2021 (Figure 1).



Note: Figures in parentheses refer to 2016 and 2021 traffic share.

Source: Cisco VNI Mobile, 2017

Figure 1: Mobile Video Growth (2018-2021).

Therefore, the importance of mobile networks to deliver such immersive multimedia is continuously growing and the New Radio (NR) access technology should take into account the efficient delivery techniques of high speed multimedia services to massive users. The requirements for multimedia broadcast/multicast service (MBMS) are documented in 3GPP TS 22.261.

5G-Xcast partners have been proposing SIs and WIs to address these requirements as part of the 5G solution. Their work also includes identifying the potential techniques to ensure the forward compatibility.

The SIs/WIs proposed or supported by 5G-Xcast partners are listed below:

SA	EBU	SP-180340, "New WID on Study on Audio-Visual Service Production (FS_AVPROD)", *3GPP TSG SA Meeting #80*, La Jolla, CA, USA, June 2018.
SA	Expway	SP-190253, "New SID: Architectural enhancements for 5G multicast-broadcast services", *3GPP TSG SA Meeting #83*, Shenzhen, China, March 2019.
SA	Expway	SP-190332, "New WID on 5G Media Streaming stage 3 (5GMS3)", *3GPP TSG SA Meeting #84*, Newport Beach, USA, June 2019.
SA1	EBU	S1-181365, "Feasibility Study on Audio-Visual Service Production (FS_AVPROD)", *3GPP WG SA1 Meeting #82***,** Dubrovnik, Croatia, May 2018.
SA1	EBU	S1-191610, "New WID on Audio-Visual Service Production", *3GPP WG SA1 Meeting #86***,** Suzhou, China, May 2019.
SA1	EBU	S1-191163, "New WID on Audio-Visual Service Production", *3GPP WG SA1 Meeting #86*, Suzhou, China, May 2019.
SA2	One2many, Expway, Nokia	S2-1901392, "Architectural enhancements for 5G multicast-broadcast services", *3GPP WG SA2 Meeting #130***,** Kochi, India, January 2019.
SA2	EBU, One2many	S2-1906720, "New SID: Study on Architectural enhancements for 5G multicast-broadcast services", *3GPP WG SA2 Meeting #133***,** Reno, Nevada, USA, May 2019.
SA4	Expway	S4-170476, "Study on MBMS User Services for IoT", *3GPP WG SA4 Meeting #93*, Busan, Korea, April 2017.
SA4	Samsung, One2many, Expway	S4-170715, "Study on V2X Media Handling and Interaction," *3GPP WG SA4 Meeting #94***,** Sophia Antipolis, France, June 2017.
SA4	Expway	S4-170719, "SAND for MBMS", *3GPP WG SA4 Meeting #94,* Sophia Antipolis, France, June 2017.
SA4	Samsung, Expway, One2many	S4-170730, "Study on V2X Media Handling and Interaction", *3GPP WG SA4 Meeting #94,* Sophia Antipolis, France, June 2017.

SA4	One2many	S4-170738, “Study Item Description on Service Interactivity (SerInter)”, *3GPP WG SA4 Meeting #94,* Sophia Antipolis, France, June 2017.
SA4	Expway	S4-180283, “New WID on Usage of CAPIF for xMB API”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180285, “New WID on FEC and ROHC activation for GCSE over MBMS (FRASE)”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180879, “New WID on xMB extension for mission critical services (MC_XMB)”, *3GPP WG SA4 Meeting #99*, Roma, Italy, July 2019.
SA6	One2many	S6-191619, "Study on Mission Critical services over 5G multicast-broadcast system", *3GPP WG SA6 Meeting #32*, Rome, Italy, July 2019.
RAN	IRT	RP-171602, “Motivation for WID on dedicated 5G MBMS for LTE”, *3GPP TSG RAN Meeting #77*, Sapporo, Japan, September 2017.
RAN	BBC, EBU	RP-171603, “New WID on dedicated 5G MBMS for LTE”, *3GPP TSG RAN Meeting #77*, Sapporo, Japan, September 2017.
RAN	Samsung	RP-171807, “New SID Proposal: Study on MBMS for NR”, *3GPP TSG RAN Meeting #77*, Sapporo, Japan, September 2017.
RAN	BBC	RP-172056, “New WID on dedicated 5G MBMS for LTE”, *3GPP TSG RAN Meeting #77*, Sapporo, Japan, September 2017.
RAN	BBC, BT, EBU, IRT, Nomor. Nokia, One2many Samsung	RP-180672, “New Work Item on 5G Terrestrial Broadcast”, *3GPP TSG RAN Meeting #80*, La Jolla, CA, USA, June 2018.
RAN	BBC, BT, EBU, IRT, Nomor, Nokia, One2many, Samsung, Expway	RP-181342, “New WID on LTE-based 5G Terrestrial Broadcast”, *3GPP TSG RAN Meeting #80*, La Jolla, CA, USA, August 2018.
RAN	Expway	RP-181706, “Revised SID: LTE-based 5G Terrestrial Broadcast”, *3GPP TSG RAN Meeting #81*, Gold Coast, Australia, September 2018.
RAN	EBU, Expway	RP-190732, “WID proposal for LTE-based 5G terrestrial broadcast”, *3GPP TSG RAN Meeting #83*, Shenzhen, China, March 2019.

CT	One2many	CP-181194, “New Study on IETF QUIC Transport for Service Based Interfaces”, *3GPP TSG CT Meeting #80*, La Jolla, CA, USA, June 2018.
CT4	Nokia, One2many	C4-183280, “New Study on IETF QUIC Transport for 5GC Service Based Interfaces,” *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.

The Tdoc RP-180672 was presented as part of the future Broadcast discussion led by Qualcomm. Qualcomm also led the discussion for the nomenclature definition. It was decided to split the SIs into two separate proposals:

- WI on 5G Terrestrial Broadcast (RP-180672)
- SI on NR mixed mode broadcast/multicast (RP-180669)

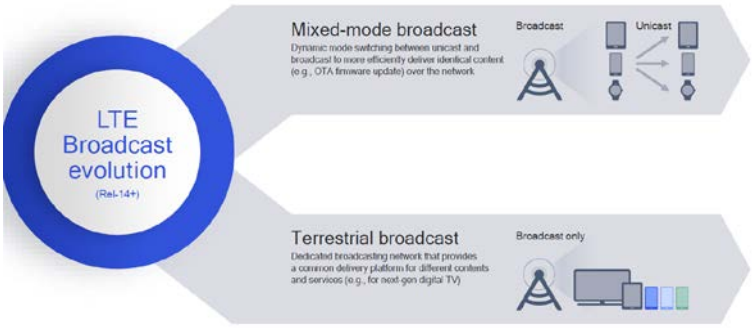


Figure 2: Two 3GPP SI proposals on future broadcast

The WI was approved and supported by many 5G-Xcast partners. The SI was not approved in 3GPP due to the lack of time units but will be considered in the future. 5G-Xcast partners have been contributing to the WI Terrestrial Broadcast and will continue monitoring and contributing to the SI Mixed Mode Broadcast/Multicast.

2.2 Contribution in 3GPP Technical Specification Groups (TSGs) and Working Groups (WGs)

5G-Xcast partners who are members of 3GPP have been actively contributing to the standardisation in 3GPP, promoting the project’s results, and fostering the support from both other partners within the consortium and companies outside the consortium. They have been actively participating in TSGs RAN (Radio Access Network), CT (Core network and Terminal) and SA (System and service Aspect) and their affiliated WGs on broadcast topics. The submitted Tdocs to 3GPP meetings are listed below.

RAN	EBU	RP-180474, “Interim report from email discussion on 5G Broadcast evolution”, *3GPP TSG RAN Meeting #79*, Chennai, India, March 2018.
RAN	BBC, EBU, IRT	RP-180652, “Information document on “Trials, Tests and Projects Relating to 5G Broadcast”, *3GPP TSG RAN Meeting #80*, La Jolla, CA, USA, June 2018.
RAN	EBU	RP-190717, “Way forward on 5G broadcast”, *3GPP TSG RAN Meeting #93*, Shenzhen, China, March 2019.
RAN1	EBU, BBC, IRT	R1-1810319, “Public service broadcaster requirements and background information relevant to LTE-based 5G

		Terrestrial Broadcast", *3GPP WG RAN1 Meeting #94bis*, Chengdu, China, September 2018.
RAN1	EBU	R1-1810320, "Scenarios and simulation assumptions for the LTE based terrestrial broadcast gap analysis", *3GPP WG RAN1 Meeting #94bis*, Chengdu, China, September 2018.
RAN1	EBU, BBC, IRT	R1-1811588, "Scenarios and simulation assumptions for the LTE based 5G terrestrial broadcast gap analysis", *3GPP WG RAN1 Meeting #94bis*, Chengdu, China, September 2018.
RAN1	EBU, BBC, IRT	R1-1812430, "Evaluation Results for LTE-Based 5G Terrestrial Broadcast", *3GPP WG RAN1 Meeting #95*, Spokane, WA, USA, November 2018.
RAN1	EBU, BBC, IRT	TR 36.776, "Evolved Universal Terrestrial Radio Access (E-UTRA); Study on LTE-based 5G terrestrial broadcast", *3GPP WG RAN1 Meeting #96*, Athens, Greece, March 2019.
RAN1	EBU, BBC, IRT	R1-1902130, "Evaluation Results for LTE-Based 5G Terrestrial Broadcast", *3GPP WG RAN1 Meeting #96*, Athens, Greece, March 2019.
RAN1	EBU, BBC, IRT	R1-1903284, "Evaluation Results for LTE-Based 5G Terrestrial Broadcast", *3GPP WG RAN1 Meeting #96*, Athens, Greece, March 2019.
RAN1	EBU, BBC, IRT	R1-1905330, "Network Simulations Regarding the Performance of the CAS", *3GPP WG RAN1 Meeting #96bis*, Xi'an, China, April 2019.
RAN1	EBU, BBC, IRT	R1-1905331, "Information For Time Variation Models", *3GPP WG RAN1 Meeting #96bis*, Xi'an, China, April 2019.
RAN1	EBU, BBC, IRT	R1-1906634, "Network Simulations Incorporating Time Variation for the CAS", *3GPP WG RAN1 Meeting #97*, Reno, USA, May 2019.
RAN1	EBU, BBC, IRT	R1-1907093, "Spectral Efficiency of New Numerologies for Rooftop Reception", *3GPP WG RAN1 Meeting #97*, Reno, USA, May 2019.
RAN4	EBU	R4-1810527, "Usage of SDL bands for dedicated MBMS", *3GPP WG RAN4 Meeting #88bis*, Chengdu, China, October 2018.
RAN4	EBU	R4-1812352, "Background to the Change Request to explicitly permit dedicated MBMS carriers to operate in the SDL bands", *3GPP WG RAN4 Meeting #88*, Gothenburg, Sweden, August 2018.
CT1	One2many, Nokia	C1-181689, "PWS in NR –clause 9.1.3.5", *3GPP WG CT1 Meeting #109*, Montreal, Canada, February 2018.
CT1	One2many, Nokia	C1-181690, "PWS in NR –clause 9.2.0", *3GPP WG CT1 Meeting #109*, Montreal, Canada, February 2018.
CT1	One2many, Nokia	C1-181711, "PWS in NR –clause 9.2.X", *3GPP WG CT1 Meeting #109*, Montreal, Canada, February 2018.
CT1	One2many, Nokia	C1-181746, "PWS in NR –clause 9.3.X", *3GPP WG CT1 Meeting #109*, Montreal, Canada, February 2018.

CT1	One2many, Nokia	C1-181647, “Service Based Interface for 5G system”, *3GPP WG CT1 Meeting #109*, Montreal, Canada, February 2018.
CT1	One2many	C1-182014, “Discussion on a transparent AMF for PWS”, *3GPP WG CT1 Meeting #110*, Kunming, China, April 2018.
CT1	One2many	C1-182634, “Corrections to table 6 and consistent use of terminology (in TS 23.041)”, *3GPP WG CT1 Meeting #110*, Kunming, China, April 2018.
CT1	One2many	C1-183005, “Removal of Extended Repetition-Period IE for NG-RAN”, *3GPP WG CT1 Meeting #111*, Osaka, Japan, May 2018.
CT4	One2many	C4-181008, “Corrections to TS 29.500”, *3GPP WG CT4 Meeting #82*, Gothenburg, Sweden, January 2018.
CT4	One2many	C4-183406, “PWS clause 4 (in TS 29.518)”, *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.
CT4	One2many	C4-183407, “PWS clause 5.1 (in TS 29.518)”, *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.
CT4	One2many	C4-183408, “PWS clause 5.2.2.8 (in TS 29.518)”, *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.
CT4	One2many	C4-183064, “PWS clause 5.2.2.x (in TS 29.518)”, *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.
CT4	One2many	C4-183409, “PWS clause 5.2.2.y (in TS 29.518)”, *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.
CT4	One2many	C4-182310, “PWS clause 6.1.2-6.1.5 (in TS 29.518)”, *3GPP WG CT4 Meeting #84*, Kunming, China, April 2018.
CT4	One2many	C4-184396, “PWS clause 6.1.X – corrections (in TS 29.518)”, *3GPP WG CT4 Meeting #85*, Osaka, Japan, May 2018.
CT4	One2many	C4-184399, “PWS clause 6.1.6 (in TS 29.518)”, *3GPP WG CT4 Meeting #85*, Osaka, Japan, May 2018.
CT4	One2many, Nokia	C4-184445, “Support for PWS-IWF”, *3GPP WG CT4 Meeting #85*, Osaka, Japan, May 2018.
SA	BBC, EBU, IRT	SP-180296, “Information document on “Trials, Tests and Projects Relating to 5G Broadcast”, *3GPP TSG SA Meeting #80*, La Jolla, CA, USA, June 2018.
SA1	EBU	S1-174144, “PMSE (Programme Making and Special Events) Vertical Description”, *3GPP WG SA1 Meeting #80*, Reno, Nevada, USA, November 2017.

SA1	EBU	S1-174145, "Low-latency audio streaming for live performance", *3GPP WG SA1 Meeting #80*, Reno, Nevada, USA, November 2017.
SA1	EBU	S1-174146, "Low-latency audio streaming for local conference systems", *3GPP WG SA1 Meeting #80*, Reno, Nevada, USA, November 2017.
SA1	EBU	S1-174147, "High data rate video streaming / professional video production", *3GPP WG SA1 Meeting #80*, Reno, Nevada, USA, November 2017.
SA1	EBU	S1-180042, "Update of subclause 5.8.2 (Low-latency audio streaming for live performance)", *3GPP WG SA1 Meeting #81*, Fukuoka, Japan, February 2018.
SA1	EBU	S1-180043, "Update of subclause 5.8.4 (High data rate video streaming / professional video production)", *3GPP WG SA1 Meeting #81*, Fukuoka, Japan, February 2018.
SA1	EBU	S1-180045, "Business relationship models for fixed & nomadic local A/V production networks relaying on public network infrastructure", *3GPP WG SA1 Meeting #81*, Fukuoka, Japan, February 2018.
SA1	EBU	S1-180046, "Role model scenario for local A/V production networks with standalone local private network operation by a vertical 3rd party", *3GPP WG SA1 Meeting #81*, Fukuoka, Japan, February 2018.
SA1	EBU, BBC	S1-183658, "Single-Camera Uncompressed Outside Broadcast Contribution", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU, BBC	S1-183659, "Single-Camera compressed Outside Broadcast Contribution", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183660, "Professional TV Production Contribution from a Multi-Camera Outside using Uncompressed Video", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183661, "Simple Live Sports Commentary", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183663, "Local deployment of a 5G cell", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183664, "Audio Streaming in Professional Live Performances", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183665, "Live production with integrated audience services", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183583, "TR 22.827 - Modifications for Definition Section", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183065, "Background Information on AV Production Use Cases", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.
SA1	EBU	S1-183703, "Intercom system for large live events", *3GPP WG SA1 Meeting #84*, Spokane, WA, USA, November 2018.

SA1	EBU, BBC	S1-190338, "pCR TR22.827 - Video Streaming in Professional Coverage of Live Performances", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190472, "pCR TR22.827 - Video Streaming of Live Events using an Airborne Relay", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190471, "pCR TR22.827 - Remote Production", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190469, "pCR TR22.827 - Single-Source Uncompressed Outside Broadcast Contribution", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190468, "pCR TR22.827 - Definitions", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190330, "pCR TR22.827 - Simple Live Sports Commentary", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190328, "pCR TR22.827 - Single-Source Compressed Outside Broadcast Contribution", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-190325, "pCR TR22.827 - Filetransfer", *3GPP WG SA1 Meeting #85*, Tallinn, Estonia, February 2019.
SA1	EBU	S1-191159, "Proposal for consolidated performance requirements of AVPROD", *3GPP WG SA1 Meeting #86*, Suzhou, China, May 2019.
SA1	EBU	S1-191160, "Proposal for consolidated service requirements of AVPROD", *3GPP WG SA1 Meeting #86*, Suzhou, China, May 2019.
SA1	EBU	S1-191165, "Normative work for the new WID for AV Production", *3GPP WG SA1 Meeting #86*, Suzhou, China, May 2019.
SA1	EBU	S1-191233, "TR22.827v1.1.0 to include agreements at this meeting", *3GPP WG SA1 Meeting #86*, Suzhou, China, May 2019.
SA4	Expway	S4-170579, "FS_MBMS_IoT_Timeplan", *3GPP WG SA4 Meeting #94*, Sophia Antipolis, France, June 2017.
SA4	Expway	S4-170582, "Skeleton for TR 26.850 MBMS for IoT v. 0.0.1", *3GPP WG SA4 Meeting #94*, Sophia Antipolis, France, June 2017.
SA4	Expway	S4-170634, "Pseudo-CR-MBMS IoT", *3GPP WG SA4 Meeting #94*, Sophia Antipolis, France, June 2017.
SA4	Expway	S4-170691, "Draft Skeleton for TR 26.850 MBMS for IoT v.0.0.2" *3GPP WG SA4 Meeting #94*, Sophia Antipolis, France, June 2017.
SA4	Expway	S4-170692, "FS_MBMS_IoT_Timeplan v2" *3GPP WG SA4 Meeting #94*, Sophia Antipolis, France, June 2017.
SA4	Expway	S4-AHI746, "Pseudo-CR on use case for FS_MBMS_IoT", *3GPP WG SA4 Conference call,* August 2017.

SA4	Expway	S4-AHI747, "Pseudo-CR on device analysis for FS_MBMS_IoT", *3GPP WG SA4 Conference call,* August 2017.
SA4	Expway	S4-AHI748, "Pseudo-CR on overview of LwM2M for FS_MBMS_IoT", *3GPP WG SA4 Conference call,* August 2017.
SA4	Expway	TR 26.850, "MBMS for IoT" *3GPP WG SA4 Meeting #94*, Sophia Antipolis, France, June 2017.
SA4	Expway	S4-170884, "FS_MBMS_IoT_Timeplan v3" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-170885, "Pseudo-CR on use case for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-170886, "Pseudo-CR on device analysis for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-170887, "Pseudo-MBMS profiles for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-170888, "Pseudo-MBMS profiles for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171003, "FS_MBMS_IoT: Proposed Draft Time Plan v4" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171004, "Pseudo-CR on use case for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171005, "Pseudo-CR on device analysis for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171006, "FS_MBMS_IoT_Timeplan" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171007, "3GPP TR 26.850 MBMS for IoT (Release 15), V0.0.4" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171018, "3GPP TR 26.850 MBMS for IoT (Release 15), V0.1.0" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171022, "Pseudo-CR on use case for FS_MBMS_IoT" *3GPP WG SA4 Meeting #95*, Belgrade, Republic of Serbia, October 2017.
SA4	Expway	S4-171202, "draft TR 26.850 MBMS for IoT, v. 0.1.1", *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-171203, "FS_MBMS_IoT_Timeplan v5", *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-171204, "Pseudo-MBMS profiles for FS_MBMS_IoT", *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.

SA4	Expway	S4-171205, “Pseudo-Update CoAP overview with block-wise transfer”, *3GPP WG SA4 Meeting #96,* Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-171206, “Pseudo-Solutions for File Repair procedure using CoAP”, *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-171207, “Pseudo-Binary FDT for FS_MBMS_IoT”, *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November, 2017.
SA4	Expway	S4-171323, “Pseudo-MBMS profiles for FS_MBMS_IoT”, *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-171327, “FS_MBMS_IoT_Timeplan v6”, *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November, 2017.
SA4	Expway	S4-171373, “3GPP TR 26.850 MBMS for IoT (Release 15), V0.2.0”, *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-171374, “FS_MBMS_IoT_Timeplan v7”, *3GPP WG SA4 Meeting #96*, Albuquerque, New Mexico, US, November 2017.
SA4	Expway	S4-AHI761, “Discussion on the binary formats for MBMS IoT”, *3GPP WG SA4 Conference call*, December 2017.
SA4	Expway	S4-AHI762, “Pseudo-CR Solution for announcement during wake-up periods”, *3GPP WG SA4 Conference call*, December 2017.
SA4	Expway	S4-AHI765, “Discussion on the binary formats for MBMS IoT”, *3GPP WG SA4 Conference call,* January 2018.
SA4	Expway	S4-AHI766, “Pseudo-CR Solution for announcement during wake-up periods”, *3GPP WG SA4 Conference call,* January 2018.
SA4	Expway	S4-AHI767, “Pseudo-CR Solution for announcement of critical data delivery”, *3GPP WG SA4 Conference call,* January 2018.
SA4	Expway	S4-AHI768, “Pseudo-CR Solution for reception report procedures”, *3GPP WG SA4 Conference call,* January 2018.
SA4	Expway	S4-AHI769, “Pseudo-CR Solution for announcement during wake-up periods”, *3GPP WG SA4 Conference call,* January 2018.
SA4	Expway, UPV	S4-180128, “pCR 26.881: Performance evaluation of AL-FEC and MCS dimensioning”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180185, “Draft TR 26.850 v1.1.0”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180199, “FS_MBMS_IoT_Timeplan v8”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180220, “FS_MBMS_IoT_Timeplan v9” *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.

SA4	Expway	S4-180180, “pCR 26.850: Binary data formats for MBMS IoT (update of S4-180073)”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180181, “pCR 26.850: Solution for announcement of critical data delivery”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180075, “Pseudo-CR Solution for announcement during wake-up periods”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-180182, “pCR 26.850: Solution for reception report procedures (update of S4-180076)”, *3GPP WG SA4 Meeting #97*, Fukuoka, Japan, February 2018.
SA4	Expway	S4-AHI778, “PseudoCR ASN.1 binary format for reception report message”, *3GPP WG SA4 Conference call*, March 2018.
SA4	Expway	S4-AHI779, “Pseudo-CR ASN.1 binary FDT instance format”, *3GPP WG SA4 Conference call*, March 2018.
SA4	Expway	S4-AHI780, “Pseudo-CR Solution for service announcement procedures”, *3GPP WG SA4 Conference call*, March 2018.
SA4	Expway	S4-AHI781, “PseudoCR Editorial changes in TR 26.850”, *3GPP WG SA4 Conference call*, March 2018.
SA4	Expway	S4-180534, “pCR to TR 26.850 - ASN.1 binary format for reception report message”, *3GPP WG SA4 Meeting #98*, Kista, Sweden, April 2018.
SA4	Expway	S4-180537, “Solution for service announcement procedures”, *3GPP WG SA4 Meeting #98*, Kista, Sweden, April 2018.
SA4	Expway	S4-180457, “Discussion on the low-end profile for MBMS IoT”, *3GPP WG SA4 Meeting #98*, Kista, Sweden, April 2018.
SA4	Expway	S4-180455, “ASN.1 binary FDT instance format”, *3GPP WG SA4 Meeting #98*, Kista, Sweden, April 2018.
SA4	Expway	S4-180620, “FS_MBMS_IoT_Timeplan v13”, *3GPP WG SA4 Meeting #98*, Kista, Sweden, April 2018.
SA4	Expway	S4-AHI799, “pCRs Evaluation of file repair solutions”, *3GPP WG SA4 Conference call*, June 2018.
SA4	Expway	S4-AHI800, “Discussion on the low-end profile for MBMS IoT”, *3GPP WG SA4 Conference call*, June 2018.
SA4	Expway	S4-AHI801, “pCRs to TR 26.850”, *3GPP WG SA4 Conference call*, June 2018.
SA4	Expway	S4-180994, “3GPP TR 26.850 MBMS for IoT”, *3GPP WG SA4 Meeting #99*, Roma, Italy, July 2018.
SA4	Expway	S4-180778, “pCR Binary SDP for low-end IoT category profile”, *3GPP WG SA4 Meeting #99*, Roma, Italy, July 2018.

SA4	Expway	S4-180780, “pCRs unresolved aspect to TR 26.850”, *3GPP WG SA4 Meeting #99*, Roma, Italy, July 2018.
SA4	Expway	S4-180781, “Conclusions of TR 26.850”, *3GPP WG SA4 Meeting #99*, Roma, Italy, July 2018.
SA4	Expway	S4-180864, “pCR TR 26.850 Solution for customized block-wise transfer using CoAP”, *3GPP WG SA4 Meeting #99*, Roma, Italy, July 2018.
SA4	Expway	S4-190471, “pCR on Consumption report”, *3GPP WG SA4 Meeting #103*, Newport Beach, California, USA, April 2019.
SA4	Expway	S4-190468, “CR 26.347-0007 rev 1 on New API providing the SA File (Release 16)”, *3GPP WG SA4 Meeting #103*, Newport Beach, California, USA, April 2019.

2.3 Contribution to DVB

5G-Xcast partners who are members of DVB also contribute to DVB by presenting results in the Technical Module - Wideband (TM-WIB) Study Mission Group.

The traditional standard High Power High Tower (HPHT) television broadcast transmission networks carry high data rate services using DVB-T or DVB-T2, and are often configured to operate as multi-frequency networks (MFNs), with a frequency reuse factor of around 5 (in other words around 5 UHF channels are required to carry one groups of services in a single DVB-T or DVB-T2 multiplex), with different channels being used in different geographical areas to avoid interference. Alternatively, regional single frequency networks (SFNs) can be used, where a single frequency is used in one geographical area, but often the frequencies used in adjacent areas would need to be different in order to avoid interference, and ultimately over a large area a similar order of frequency reuse may well be obtained. Whilst high order modulation might be used on any one channel, e.g. 256-QAM with a code rate of 2/3, which has a raw spectral efficiency of 5.3b/s/Hz, the reuse factor of 5 means that the overall spectral efficiency is reduced to around 1b/s/Hz, especially after considering overheads such as guard intervals, reference pilots and signalling requirements.

5G-Xcast proposed a basic WiB (Wideband reuse 1) concept [1] to use much lower order modulation coupled with a frequency reuse factor of 1, which means the same channels being used in all areas, to achieve the similar result. The lower order modulation means signals are much more robust against interference, but interference cancellation techniques would also need to be used. The loss of capacity from the lower modulation mode is compensated by using a wider bandwidth channel. A main advantage of this proposal is that it allows a significant overall reduction in transmission power (Figure 3).

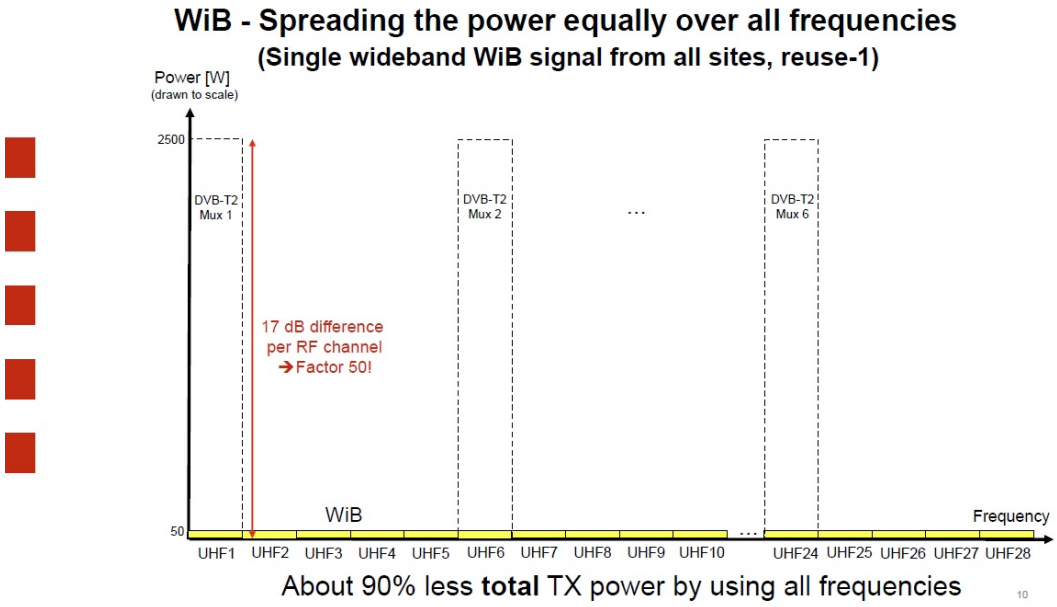


Figure 3: Basic WiB concept.

5G-Xcast contributions to DVB are listed as below:

IRT UPV	J.J. Gimenez, TM-WIB0049, "Fundamentals of 5G Wideband Broadcasting," *DVB Meeting*, London, UK, June 2017.
IRT UPV	J.J. Gimenez, TM-WIB0050, "Implementation Aspects of 5G Wideband Broadcasting," *DVB Meeting*, London, UK, June 2017.
IRT UPV	J.J. Gimenez, TM-WIB0074, "Methodology Approach to SIC in Network Simulations," *DVB Meeting*, Stockholm, Sweden, September 2017.
IRT UPV	J.J. Gimenez, TM-WIB0076, "Network Simulations with SIC in MFN and SFN," *DVB Meeting*, Stockholm, Sweden, September 2017.
BBC	Lucas Pardue, Richard Bradbury, TM-IPI A176, "Adaptive Media Streaming Over IP Multicast", March 2018.
Expway	TM-IPI3566, TM-IPI ABR multicast, "Interface M Operations and FLUTE Profile - Expway proposals for improving chunked transmission mode", May 2019.
Expway	TM-IPI3608, TM-IPI ABR multicast, "Multicast operation on Demand", May 2019.

2.4 Contribution to IETF

5G-Xcast contribution to IETF is in the following list.

BBC	Lucas Pardue, Richard Bradbury, "Hypertext Transfer Protocol (HTTP) over multicast QUIC", draft-pardue-quic-http-mcast-02, Network Working Group, February 2018.

3 Exploitation

Project partners have been and will keep leveraging on the 5G-Xcast features in order to increase their competitive advantage and improve their products and services related to media and broadcast. More specifically, depending on the partners' type (university, research institute or industry player), activity (broadcaster, operator or vendor) and size (large enterprises or SMEs), the consortium members target some or all of the following objectives:

- Enhance products focused on media and broadcast and develop future 5G products and services.
- Expand their IPR (Intellectual Property Rights) portfolio.
- Influence the standardisation bodies for adoption of the new features.
- Increase knowledge and know-how to be leveraged on for future research projects.
- Disseminate scientific findings in major research and academic events

Broadcasters

Broadcasters face a constant challenge to enhance their M&E content and are always innovating to optimise the content and its delivery to meet the needs of their subscribers. 5G-Xcast has among its members the BBC, a major public broadcaster, and the EBU, an association of public service media providers.

The **BBC** uses the results from the 5G-Xcast project to better understand the capabilities of 5G in the realm of M&E. This feeds into its wider Research & Development work. The knowledge gained helps optimise the delivery of the BBC's existing services over future 5G networks. The understanding gained from the project also helps shape the development of new and innovative offerings enabled by 5G and underpinned by an Internet-first BBC, while ensuring that these are available to licence fee payers as widely as possible across different networks and devices.

The **EBU** is an association of public service media providers. The EBU facilitates collaboration between its members as well as with wider industry, standards developing organisations, regulators and academia. The EBU sees 5G-Xcast to pave the way towards sustainable solutions for a large-scale distribution of audio-visual media services over mobile, fixed and broadcast networks, taking full advantage of the 5G capabilities, in order to meet the future needs of the European audio-visual media sector. The technical results and experience gained from the 5G-Xcast project are used in EBU's work on the evolution of audio-visual media services, in particular with respect to new formats and novel distribution options. In addition, the project's results are used for EBU's contributions to the relevant standardisation work.

The EBU has undertaken, in cooperation with its Members, a number of activities that are related to the 5G-Xcast project. In particular, a technical project group[1] has been set up to build technical competence within the EBU community in the domain of mobile technologies. The group' principal tasks are to:

- Undertake detailed technical studies of 4G and 5G and monitor their respective standardisation roadmaps;

[1] EBU Project group Mobile Technologies and Standards - https://tech.ebu.ch/groups/mts

- Follow the work in the relevant standards developing organizations, in particular 3GPP, and prepare contributions to their work on the issues of relevance for public service media;
- Formulate and coordinate EBU positions on relevant mobile standardisation issues;
- Share knowledge and relevant information with EBU Members, including those not actively involved in its work;
- Provide expert advice on mobile technologies to the EBU Members.

The above mentioned activity has helped the EBU member broadcasters to be involved in a number of 4G and 5G tests and trials. Further information about some these trials is provided in a contribution to 3GPP RAN Plenary (RP-180652).

Furthermore, the EBU is consulting and cooperating with the industry and other 3GPP stakeholders with the view of advancing the normative work on 5G multicast/broadcast functionalities as well as the use of 3GPP technologies in content production. This has resulted in a number of inputs to 3GPP, as reported in sections 2.1 and 2.2.

A broader impact of the EBU's involvement in 5G-Xcast includes:

- Raising awareness outside the broadcast sector of the requirements of public service media organisations, in particular in content distribution.
- Providing relevant information to the EBU Members about the state-of-the-art mobile technologies as well as 5G developments, with the view of assisting them in developing their own future distribution strategies.
- Growing mutual understanding between broadcasters and the mobile industry which might facilitate cooperation beyond the scope and the lifetime of the project.

Telecom Operators

Telecom operators are continuously working to improve their mobile network capabilities in order to efficiently serve their customers. Broadcast solution can sometimes relieve the network from a multitude of one-to-one connection and improve the efficiency. Furthermore, some operators have both cellular and fixed networks sometimes delivering the same content. In this case, network convergence can be a trigger for a better overall efficiency and flexibility. Two major European operators are part of the 5G-Xcast consortium:

British Telecom's recent purchase of EE presents a huge opportunity to exploit 5G broadcast and convergence technologies. BT provides its own TV service, as well as production studios for its own sport channels. Indeed, BT was the first operator to launch a live UHD channel in Europe. BT's strategy is to leverage its fixed and mobile network capability to deliver a unique TV service as well as offering the best possible quality for third party services. 5G broadcast is essential for content delivery on this scale. Dynamic convergence technologies permit easy integration of on-net and off-net services as well as highly efficient scaling in the core and aggregation networks to make these services cost-effective.

Telecom Italia exploits the results of the 5G-Xcast project in different ways to optimise usage within its network. The new and innovative concepts studied in the project with a view of achieving a coordinated usage of currently "isolated" networks to deliver multicast/broadcast services provide Telecom Italia with guidelines for optimized network design and operation based on usage scenarios and related requirements with positive impacts on both the customer experience and consequent business return. In regard to the 5G RAN, the advanced resource management policies explored in the project are exploited both directly in the design and operational phase in order to

achieve an optimized usage of the cell radio resources. The results of 5G-Xcast allow TIM to exploit the increased interest of the broadcasting companies in MBMS solutions by performing collaborations and trials. Due to its active role in several standardisation and specification groups, Telecom Italia also exploits the outcomes of the project to define its position and to provide contributions.

Telecom Vendors

Telecom vendors strive to continuously innovate to provide their customers with solutions compliant with the latest features and standard releases. The 5G-Xcast project counts in its member telecom vendor having customers that are operators (using network infrastructure) or individuals (using mobile devices or TV sets). Continuous innovation and future 5G products represent the essence of the exploitation for telecom vendors.

Nokia Networks is a leading global system provider and enabler of telecommunications services, aiming at developing cutting-edge innovations that are powering the next revolution in computing and mobility: the "programmable world" where things, as well as people are connected. Nokia provides the world's most efficient mobile networks, the intelligence to maximise the value of those networks, and the services to make everything work seamlessly. Nokia predicts that beyond 2020, very diverse and significantly increased service requirements will render a novel fifth generation of mobile communications networks necessary, which will be a symbiotic integration of novel air interface variants tailored towards specific service needs and communication environments, with an evolution of the existing standards. Nokia sees the 5G-Xcast project as an essential platform for developing the technology related to 5G multicast and broadcast technologies, mainly targeting the M&E vertical where the requirements for 5G networks are expected to be significantly higher than legacy technologies. Nokia will exploit the research work performed in the 5G-Xcast project to further strengthen its competitiveness, patent and product portfolio, and to utilize this to provide a timely roll-out of a most meaningful and efficient 5G multicast/broadcast technology to its customers, with the aim of providing a converged architecture for provisioning such services. Nokia will leverage the acquired knowledge and the findings of the 5G-Xcast project in contributions to standards developing organizations defining multicast/broadcast solutions in 5G networks such as 3GPP, which started its work on multicast/broadcast solutions for the 5G system by study on architectural enhancements for 5G multicast-broadcast services [SP-190442].

Samsung Electronics sees the 5G-Xcast project as an important opportunity to enhance the support of broadcast and multicast in mobile handset. Samsung also leverage the 5G-Xcast project to explore ways to support converged media delivery to TV sets. As a member of many mobile and TV standardisation bodies and leader of dissemination and standardisation activities, Samsung use the project to ensure that the project concepts are promoted among the corresponding SDOs. 5G simulations is an important part of the 5G solution evaluation. Samsung has developed 5G physical layer simulators to study the performance of the proposed solutions as well as used simulation for IMT2020 submissions.

SMEs

A large part of the 5G-Xcast consortium is composed of SMEs working in niche markets around broadcast and media delivery. The impact of 5G-Xcast is bigger on these SMEs than on large enterprises. The strong participation of SMEs in the project enables a faster adoption of 5G-Xcast technologies in the market.

Broadpeak's objective with 5G-Xcast is to drive the adaptation of its CDN solution, which currently allows content caching on fixed networks and leveraging of the multicast capabilities of ADSL, cable and satellite networks, to the 5G mobile network. The key findings in its exploitations are: the best locations inside a mobile network to cache content, what metrics should trigger content caching or the allocation of multicast resources in the backbone and backhaul, how end-to-end latency can be reduced, and how the streaming requests can be redirected to the most relevant caching location.

BundlesLab provides development and consultancy services related to wireless communication. BundlesLab is in early stages of defining their novel technologies and software development kit (SDK) product designed for mobile devices. This SDK will be integrated into 5G mobile devices through collaboration with manufacturers such as Samsung and Nokia. BundlesLab intends to promote the multilink technology once verified to potential customers as part of the 5G convergence layer at the network. While collaborating with the project and the 5G-Xcast multilink PoC, BundlesLab gains the right insights, connections and knowhow of the challenges in the 5G mass market. BundlesLab will continue to collaborate with strategic partners and to enhance their commercial platform.

Expway Expway has extended its BM-SC features by developing the xMB interface standardized in 3GPP Release 14 allowing the provisioning of OTT friendly services in the BM-SC. Expway has developed the MooD (Multicast/Broadcast operation on Demand) feature on both network and terminal sides that allows the system switches between unicast and multicast/broadcast delivery according to the audience size. The Expway middleware supporting MooD that has been integrated into Samsung Galaxy phones has been commercialized by Telstra operator in Australia. Expway acting as a rapporteur has conducted the study on the optimization of MBMS User Services for resource-constrained IoT devices in 3GPP SA4 working group. Thanks to 5G-Xcast, Expway has developed a new Multicast ABR solution compliant with the specification that is being standardized by the DVB. Since 2019, Expway has been actively participating and contributing to the DVB Multicast ABR specification. The newly developed Multicast ABR solution combining with the well-known Expway's LTE-Broadcast products create a unique position for Expway to offer standard-compliant solutions and products in the 5G converged network including fixed and mobile to help the network operators to deal with the efficient use of network resources using MooD. The concept of the 5G converged network has been jointly demonstrated with BT at the end of the project using commercial devices (i.e. phones, tablets, home gateways).

Fairspectrum exploits the use case and requirement discussions to understand the demand for the spectrum-sharing solutions emerging from the convergence of mobile and broadcasting technologies. Fairspectrum adapts its spectrum-sharing technology to fulfil the requirements of the operators that have multicasting and broadcasting services. Fairspectrum ensures that its protocol and management interfaces are integrated with the legacy systems used by the multicasting and broadcasting operators with an emphasis on the systems of the other network equipment providers participating in the project. Fairspectrum leverages the collaboration with the other partners, project pilots and test-beds, and the results of the project when marketing the Fairspectrum experience and services.

IRT is a specialised broadcast and multimedia technology institute, jointly owned by the Public Service Broadcasters of Germany, Austria and Switzerland. As a non-profit making SME, IRT is dedicated to technical research and development for the benefit of the public while also offering commercial services and products. Through its active involvement in the 5G-Xcast project, IRT further complements and extends its excellent

media technology expertise into the field of 5G – a deciding factor when strategically consulting and supporting broadcasters and parties in far-reaching technology decisions regarding future content distribution. Through 5G-Xcast, IRT offers new test facilities for 5G technologies and the project results also help advance IRT's frequency planning tool, FRANSY. In addition, tested and published 5G-Xcast outcomes corroborate IRT's role in competitive 3GPP standardisation groups.

Nomor as a small company mainly focussed on research and consulting work, plans to further develop their expertise in the related fields as a sustained basis for future projects. Within 5G-Xcast and as a joint effort with our activities in 5G-MoNArch, Nomor has made considerable progress in developing a 5G RAN simulator that can, after the project, be used by customers for testing of a wide variety of higher-layer applications or internally for consulting projects and research. It has been calibrated against 3GPP system-level simulators and used for partial evaluation of 3GPP's proposal for IMT-2020, an activity that is to be continued beyond the lifetime of 5G-XCast. Nomor is also publishing papers and preparing demos for various industry conventions like EUCNC'19 to promote the 5G-Xcast technology components. As of June 2019 Nomor has already acquired a number of consulting projects based on system aspects and performance analysis of 5G, published two conference papers and two white papers, produced small video clips from their 5G simulator for illustrative purposes in their 5G training courses and is, together with partners from 5G-XCast, in the process of writing several papers documenting the work done in the project.

One2many intends to develop its PWS core net product (called BM-SC and MBMS GW in LTE-architecture) according to the 5G architecture developed in 5G-Xcast. This product will be the basis for One2many sales in the future. Its customers are expected to be mobile operators and the system is expected to work independently, being transparent for verticals. Furthermore, one2many has contributed in 3GPP to the specification of Cell Broadcast (Warning Message Delivery) in 5G, which is used in the deployment option together with Transparent Multicast. One2many is developing its core net Cell Broadcast Centre to support 5G.

LiveU is an established world leader in live media gathering over cellular and wireless networks. LiveU's portfolio of technologies and products is used for various markets such as the broadcast and security industries. The current dominant market for LiveU is news gathering with more than 1000 customers - networks and international TV stations, national and local, making use of thousands broadcasting systems manufactured and developed by LiveU. LiveU is a contributor and 5G-xcast liaison into the NEM/Net World 2020 Media slice WG. In the WG work, LiveU included its 5G-Xcast results on 5G media slice definition into the first deliverable. One main contribution is that multicast and broadcast should be supported by this new media slice.

Universities

Universities play a central role in expanding the knowledge, teaching and training future engineers working in the fields of telecommunications. They also have the leading role in disseminating research results in major scientific venues. To remain competitive for future research project calls, universities need also to expand their circle of competence and deepen their understanding of future broadcast and multimedia challenges. 5G-Xcast has three universities and having broadly similar exploitation plans.

To maximise the benefits of participating in 5G-Xcast, **Turku University of Applied Sciences, University of Surrey and Universitat Politecnica de Valencia**, as higher education partners, have exploited the results and experience gained from the project

in further expanding their knowledge base in the field and staying competitive for future wireless research initiatives, in enhancing their teaching scope and quality by introducing new project findings and cutting edge technologies into the teaching and research syllabus at undergraduate, postgraduate teaching and research. Universities contribute to the dissemination of the results through publication of scientific articles in relevant journals and international conferences. When required academic partners assist SMEs with dissemination and publications by videos and conference booth presentations.

4 Innovations

5G-Xcast has published numerous research papers to disseminate the innovations achieved during the project period [2]. Moreover a patent is also filed:

February 2019	System and method for distributing multimedia public warning alerts in a mobile telecommunications network	One2Many

The patent is to solve the problem on the ability to trigger automatic receipt of multimedia PW message on 5G. The idea is utilizing CB as a means to provide information to UE of ongoing alert, including links to contents delivered over multicast or broadcast.

5 Conclusions

In this document, we summarise the activities in two aspects: activities that 5G-Xcast partners have been carrying out in various SDOs, and activities of exploitation inside each of the partners. In the aspect of 3GPP activities, the contributions from 5G-Xcast partners to introduce new Sis and new WIs on 5G MBMS as well as the various contributions in TSGs and WGs are described. In addition to that, the work in the DVB-WiB group is described and the 5G-Xcast partners' contributions are listed. 5G-Xcast also reaches out to contribute to IETF. Moreover, the exploitation of the project results and the innovations obtained has been explained. 5G-Xcast partners are leveraging on the project in various ways as seen fit to their nature and needs. Finally, the innovation activity is summarised in terms of dissemination and patent filing. Both kinds of activities well disseminate the results achieved by 5G-Xcast.

References

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