Linear Television Broadcasting over 5G Networks

Spectrum, Regulatory and Business Considerations

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1

Agenda

- **Spectrum Demands for TV over 5G Networks**
  - 5G Unicast Delivery
  - 5G Broadcast Delivery
  - Conclusions
- **Regulatory changes for TV over 5G Networks**
  - Network Requirements for FTA Services
  - Must-Carry Regulations
  - FTA Service Availability
  - FTA Picture Quality
  - FTA Transmission and Encryption
- **Business case for TV over 5G Networks**
  - 5G BC for Connected Devices
  - 5G BC for TV Sets and STBs
  - Conclusions

2

Spectrum Demands for TV over 5G Networks

5G Unicast Delivery

To calculate the spectrum demands for carrying FTA services over a 5G unicast network:

1. we first model the FTA viewing situation
2. followed by defining the bitrate requirements for the various types of FTA services
3. and model the spectral efficiency of 5G services
4. resulting in the spectrum demands for TV over 5G networks

3

Spectrum Demands for TV over 5G Networks

5G Unicast Delivery

Step 1. Viewing scenarios

- We calculate the spectrum required to carry traffic at peak hour, typically between 7 – 9 am and 5 - 7:30 pm
- We consider that the average household size is 4 people resulting in an average of 1250 households per cell

Viewing scenario	Household viewing situation	Percentage of Households with given viewing situation in each cell	Number of unicast streams per cell, at peak hour
1	4 people, each viewing a different FTA service, at peak hour.	100%, all households	5,000
2	4 people, all viewing the same FTA service, at peak hour	As above	1,250
3	As above	50%	625
4	As above	25%	312

4

Spectrum Demands for TV over 5G Networks

5G Unicast Delivery

Step 2. Bit rate requirements per type of service

- The current most efficient video codec is H.265/HEVC
- We also consider the next generation video codec H.266/VVC
  - VVC is 40 - 50% more efficient than HEVC for UHD
  - VVC is approx. 30% more efficient for HD and SD

Typical bit rates per FTA service type

Resolution		Bitrate (H.265) (Mbps)	Bitrate (H.266) (Mbps)
UHD (4K)	3840 x 2160	16	8
FHD (2K)	1920 x 1080	8	4
HD (HD ready)	1280 x 720	4	2
SD	720 x 576	2	1

Spectrum Demands for TV over 5G Networks

5G Unicast Delivery

Step 3. 5G spectral efficiency

- We use 2 scenarios
  - Rooftop antenna: spectral efficiency = 6 bps/Hz (256 QAM, R=0.73)
  - Mobile and indoor: spectral efficiency = 3 bps/Hz (64 QAM, R=0.5)
- No MIMO due to sub-1 GHz band
- Frequency reuse ratio = 3

5G Modulation orders and spectral efficiency (non-MIMO)*

Modulation	Spectral efficiency using mean FEC rate (bps/Hz)
QPSK	0.71
16QAM	2.02
64QAM	3.92
256QAM	6.37

* We use the mean FEC rate for each modulation order, see table 5.1.3.1 in 3GPP TS 38.214 V16.7.0 (2021-09)

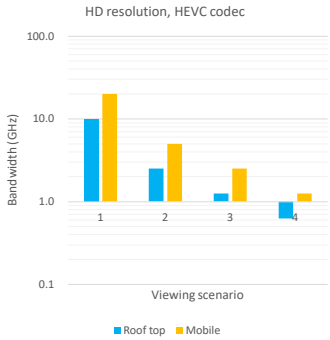
Spectrum Demands for TV over 5G Networks

5G Unicast Delivery

Step 4. Calculation results (1/2)

- Average bandwidth required per network cell in GHz

Total bandwidth (in GHz) per cell for unicast delivery using H.265/HEVC video coding



7

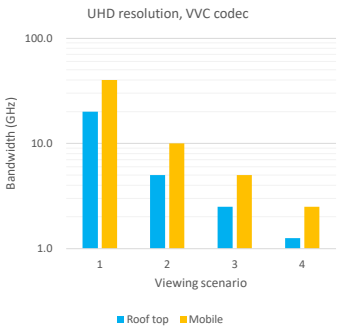
Spectrum Demands for TV over 5G Networks

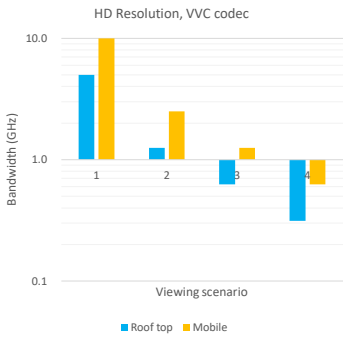
5G Unicast Delivery

Step 4. Calculation results (2/2)

- Average bandwidth required per network cell in GHz

Total bandwidth (in GHz) per cell for unicast delivery using H.266/VVC video coding





8

Spectrum Demands for TV over 5G Networks

5G Unicast Delivery

Summary

Viewing scenario	Household viewing situation	Percentage of Households	Service type/ Coding	Required spectrum - Rooftop	Required spectrum – Mobile and indoor
1	4 people, each viewing a different FTA service	100%	UHD/HEVC	80 GHz	40 GHz
3	As above	50%	HD/HEVC	1.3 GHz	2.5 GHz
4	As above	25%	HD/VVC	0.3 GHz	0.6 GHz

TV unicast delivery only
NO OTHER TRAFFIC

Sub 1 GHz downlink spectrum is typically around 0.125 GHz

- Using the mid-range bands (1.8 – 4 GHz) it is unlikely that sufficient spectrum will be available
  - Mid-band operation will require increased number of cells within the assumed area radius of 2 km (approx. 4 - 6 sites)
- Using the high-range bands (20 - 70 GHz) will provide adequate spectrum for most situations
  - High-band operation will require increased number of cells within the assumed area radius of 2 km (typically over 20 sites)

Spectrum Demands for TV over 5G Networks

5G Broadcast Delivery

Assumptions

- The number of television services is limited by the amount of spectrum that is available
- We estimate the maximum number of services which can be provided in the current spectrum, using a few basic assumptions:
  - Frequency reuse factor = 5
  - Use the same UHF spectrum as used for DTT (ATSC 3.0 in USA, DVB-T2 in Europe)
  - USA DTV spectrum = 470 – 608 MHz, resulting in maximum bandwidth per area of 27.6 MHz
  - Europe DTV spectrum = 470 – 698 MHz, resulting in maximum bandwidth per area of 45.6 MHz
  - We use the spectral efficiency based on DVB-T2*
  - Fixed rooftop reception uses 256 QAM
  - Portable reception uses 64 QAM

* See table 5 of EBU TR029, "DVB-T2 single frequency networks and spectrum efficiency"

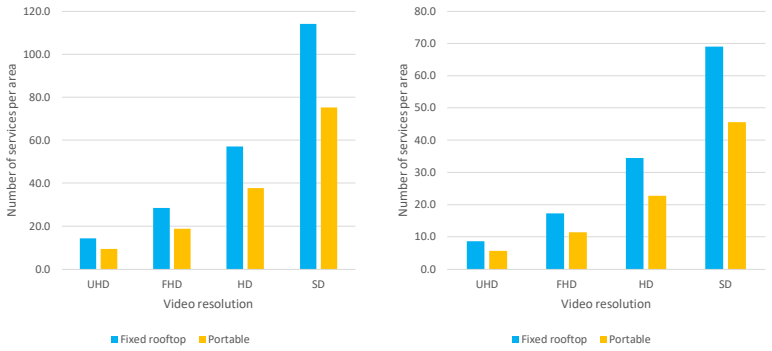
Spectrum Demands for TV over 5G Networks

5G Broadcast Delivery

Calculation results (1/2)

- Maximum number of services per area

Average number of services per area when using the H.265/HEVC codec – left = Europe, right = USA



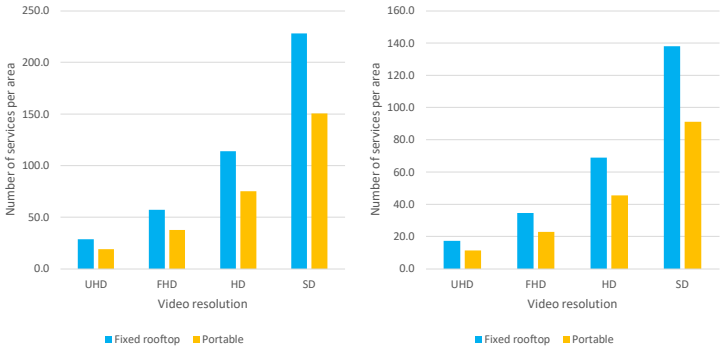
Spectrum Demands for TV over 5G Networks

5G Broadcast Delivery

Calculation results (2/2)

- Maximum number of services per area

Average number of services per area when using the H.266/VVC codec – left = Europe, right = USA



Spectrum Demands for TV over 5G Networks

5G Broadcast Delivery

Summary

- For HEVC, Europe, UHD
  - Fixed rooftop services = 14
  - Portable services = 9
- For VVC, Europe, UHD
  - Fixed rooftop services = 28
  - Portable services = 18
- USA numbers are similar but scaled lower due to less available spectrum
- It is not unusual to have 50 to 100 FTA services available in populated areas
- 5G BC, or 2nd generation DTTB will not be able to deliver that many UHD services forcing TV broadcasters to deliver a mix of SD, HD and UHD services

Spectrum Demands for TV over 5G Networks

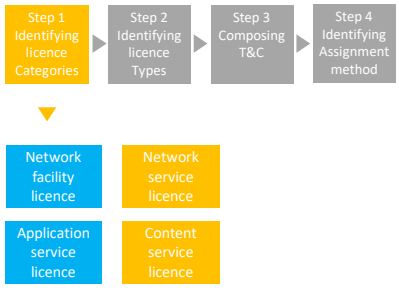
Conclusions

- 5G Unicast delivery of FTA TV services is not feasible in the Low Frequency band (sub 1 GHz)
- 5G Unicast delivery of FTA TV services is marginally feasible in the Mid Frequency band (1 - 4 GHz)
  - BUT will require an increased number of transmission sites, approx. 4 - 6 times sub 1 GHz
- 5G Unicast delivery of FTA TV services is feasible in the High Frequency band (20 – 70 GHz)
  - BUT will require an increased number of transmission sites, over 20 times sub 1 GHz
- 5G BC, or 2nd generation DTTB will not be able to deliver all services in UHD resolution
  - TV broadcasters will need to deliver a mix of SD, HD and UHD services
- Film and TV shows provided at UHD resolution will increasingly be delivered via VOD (mobile or fixed line delivery)
- FTA TV will increasingly focus on news, sports and live events

Regulatory changes for TV over 5G networks

Network Requirements for FTA Services

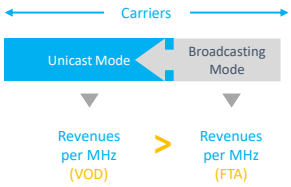
- Traditionally, content carried over telecommunications networks has been considered a private matter. Operators are supposed to only carry traffic: "*mere conduit*" principle
- FTA services are often defined in a Broadcasting or Media Act (and Code of Conducts), stipulating:
  - Number of national/regional services
  - Editorial content requirements per service
  - Advertising limits
- However, FTA services are ***also*** regulated in terms of their distribution:
  - Must-carry rules
  - Service availability
  - Picture quality
  - Transmission/encoding/encryption standards
- These FTA ***network*** requirements are not common for MNOs



Regulatory changes for TV over 5G networks

Must-carry Regulations

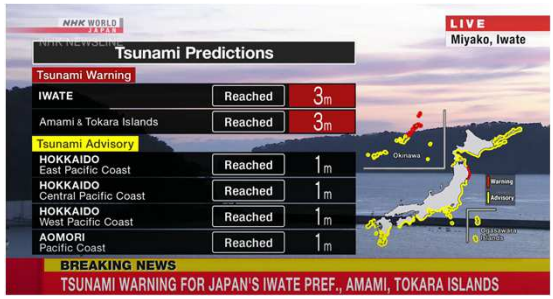
- MNOs having 5G BC will balance their traffic between unicast and broadcasting mode
  - Multicast and Broadcast Service (MBS), a Release 17 feature, provides switching the available carrier capacity automatically from unicast to broadcast mode
- However, for FTA services, which must be carried on a 24/7 basis, such capacity allocation to broadcasting mode would be permanent
- FTA services should be 'free'. It should be checked if the MNO's SIM based solution legally comply with the definition of 'free'
- Delivery of UHD services to large screens over 5G ***unicast*** is not feasible. Hence, any FTA must-carry rule including (U)HD services, will need to be delivered over 5G BC, again limiting the MNO's traffic management options



Regulatory changes for TV over 5G networks

FTA Service Availability

- FTA services delivered over 5G networks need extra safeguards for having these services available in time of national emergencies or disasters
- MNO networks suffer traffic overloading in times of national distress
- A 5G network balancing traffic between unicast and broadcasting mode will still be exposed to traffic overloading
- FTA services should be permanently allocated to broadcasting mode and traffic balancing between unicast and broadcasting mode should be excluded
- Again limiting the MNOs traffic management options



Regulatory changes for TV over 5G networks

FTA Picture Quality

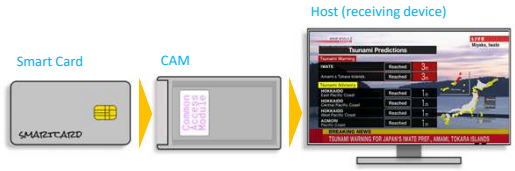
- Managing the Quality-of-Service (QoS) of FTA services carried over 5G BC ***unicast*** mode is more challenging
- Video service providers agree with ISPs and MNOs that their services have priority over other traffic, as to ensure a minimum broadband speed is made available to their subscribers
- However, ***net neutrality*** rules may hamper these possibilities for prioritising video traffic
- Net neutrality rules apply to internet traffic = unicast traffic ≠ broadcast traffic
- Automatic traffic balancing between unicast and broadcasting mode (MBS), may need to be restricted or alternatively net neutrality regulations should facilitate for MBS

EU	US	Australia	Malaysia
• No blocking, throttling or paid prioritisation • Congestion management: exceptional and temporary situations • Zero-rating: under discussion	• No blocking, throttling or paid prioritisation • Zero-rating causes conflicts	• Most users have limited data bundle • Discussion in early phase	• No clear policy • Some NGO express concerns on freedom of expression

Regulatory changes for TV over 5G networks

FTA Transmission and Encryption

- To protect consumers from purchasing non-compatible receivers, both the transmission and receiver side are regulated for (FTA) TV services
- For FTA services delivered over 5G ***unicast*** the transmission standards are IP-based standards
  - IP-based viewing of audio-visual content is mostly paid-for or subscription-based by which the service provider ensures that the correct app and drivers are installed on the user device
- FTA services 5G-BC delivered = FTA services DTTB delivered. Hence 5G BC standard and video coding should be stipulated for TV manufacturers to incorporate in the TV set
- For DTTB enabled TV sets the regulator stipulates no embedding of Conditional Access in the TV set as to prevent the TV set being dependent on the service provider. Similarly, for 5G based broadcasting, the regulator should avoid the TV set being dependent on the MNO



Business case for TV over 5G Networks

5G BC for Connected Devices

- Key CAPEX driver will be number of additional transmitters to generate the 5G BC signals
- 5G BC transmitter equipment is OFDM based equipment. 5G BC equipment will be comparable to low power DTTB transmitter equipment:
  - CAPEX for low power OFDM DTTB transmitter: USD 30k
  - 1,000 cells (for covering a large city of 5m people): USD 60m
  - 10-year linear depreciation and WACC of 15% results in required annual revenue > USD 12m for a single MNO
- Required additional revenues should be generated by offering linear television services, including FTA and any pay-tv services, next to VOD unicast services
- Without a fundamental change of viewing behaviour, the expected additional revenues from FTA services is small

Share of video views by length (Q4 2020) – all connected devices

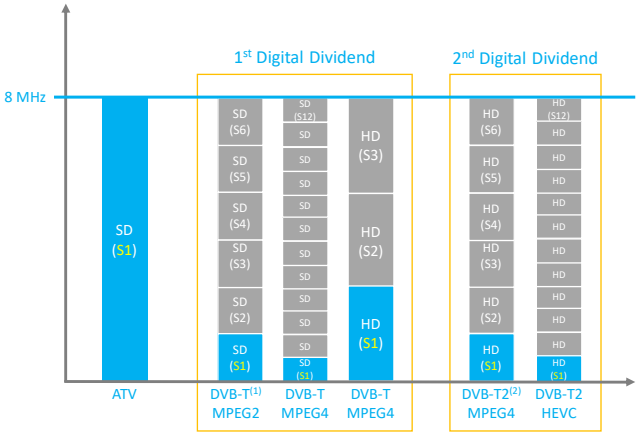
Content type	0-5 min	6-20 min	21-40 min	41+ min
Corporate Communications	71%	22%	4%	3%
Entertainment	71%	7%	8%	15%
Marketing and Sales	82%	8%	4%	6%
News	90%	3%	2%	4%
Retail	97%	2%	1%	1%
Sports	89%	4%	1%	6%

Source: Brightcove

Business case for TV over 5G Networks

5G BC for TV Sets and STBs

- 5G BC is not fundamentally different from 2nd gen DTTB standards. Implementation in smart TV sets and STBs will be at best similar in cost terms:
  - 5G BC in TV sets and STBs will require system changes as 5G unicast traffic is absent or managed differently as compared to mobiles
- 5G BC introduction would require a transition period in which both the DTTB and 5G BC standards are supported in TV sets:
  - No technical gains for having the new 5G transmission standard
  - ***In contrast*** with the migration from analogue TV to DTTB and from 1st to 2nd gen DTTB



(1) Net bit rate: 24 Mbit/s (64QAM, CR 2/3)
(2) Net bit rate: 40 Mbit/s (256 QAM, CR 2/3)

Business case for TV over 5G Networks

Conclusions

- 5G BC as an alternative for DTTB delivery of FTA services requires NRAs to impose additional regulations on MNOs:
  - MNOs to permanently allocate a part of their network capacity to 5G BC
  - Other regulatory measures for protect viewers from purchasing non-compatible receivers
- The business case of delivering FTA services over 5G BC seems feeble because the additional FTA revenues for MNOs are deemed to be relatively small:
  - Most video consumption on connected devices is viewing of short-form video content (delivered over unicast)
- 5G BC should not be viewed as a DTTB replacement. A better model would be to combine DTTB with 5G BC:
  - DTTB focuses on FTA service delivery, albeit with a smaller number of services in UHD quality
  - 5G networks continue to deliver VOD services, whereby 5G BC/MBS can be deployed as an advanced traffic management tool to further increase the capacity of mobile networks

Thank you

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