# Comparison of ATSC 3.0 and 5G Broadcast: Performance and Network Expense

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# Why ATSC 3.0 for Terrestrial Broadcast?

- ATSC 3.0 PHY is purpose-built for broadcast
- Superior over current 3GPP MBMS solutions for downlink broadcast/multicast
- Significant network expense (CAPEX and OPEX) savings
- Very compelling case to add to a future 3GPP release
- This presentation includes a performance comparison with 5G-Broadcast (3GPP Rel-16/17), a.k.a FeMBMS

# ATSC 3.0 Status in S. Korea

- ATSC 3.0 delivering 4K-UHD started in Seoul metro area (May 2017), extended to major cities (Dec. 2017), and will be nationwide by 2025
- New frequency bands in 700 MHz were assigned for ATSC 3.0 (Simulcasting: ~ 2027)


- Successfully demonstrated high quality mobile broadcast + 4K-UHD in a single RF channel for 2018 Winter Olympics (PyeongChang)

ATSC 3.0 mobile receiver installed in a shuttle bus over Olympic village


Inside the bus introduced by WRAL-TV (U.S.)

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# ATSC 3.0 Status in S. Korea

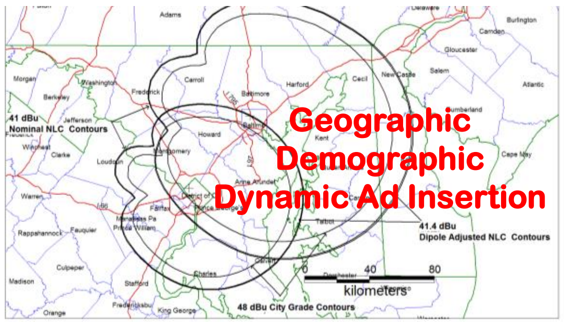


## Enhanced TV

**Mobility**



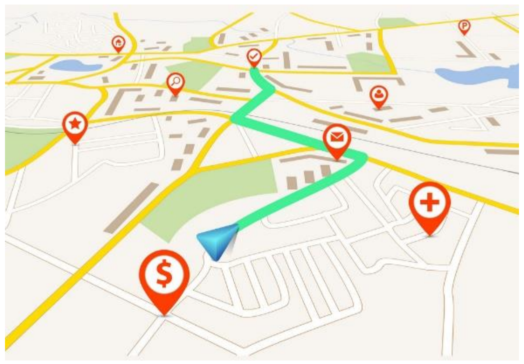
**Quality**




**Targeting**

## Datacasting

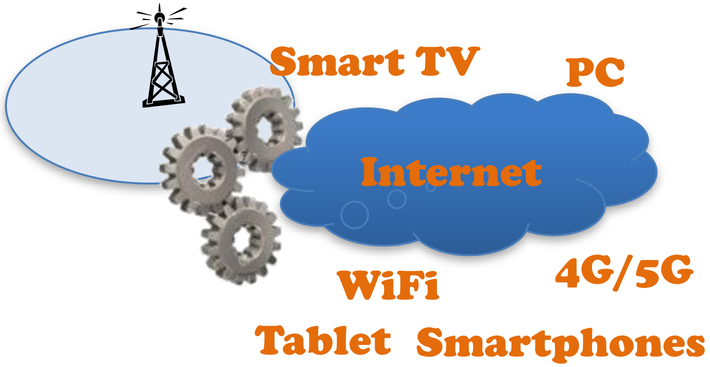
**Navigation Updates**




**Multimedia Files**

**Apps and Data**

## Convergence




# ATSC 3.0 Status in S. Korea - Consumer Devices

## TV



In Korea, all Samsung and LG UHDTV (manufactured after 2017) are ATSC 3.0 ready!!

## STB




## Others


- Dongle receiver for existing device
- Home gateway for WiFi re-distribution

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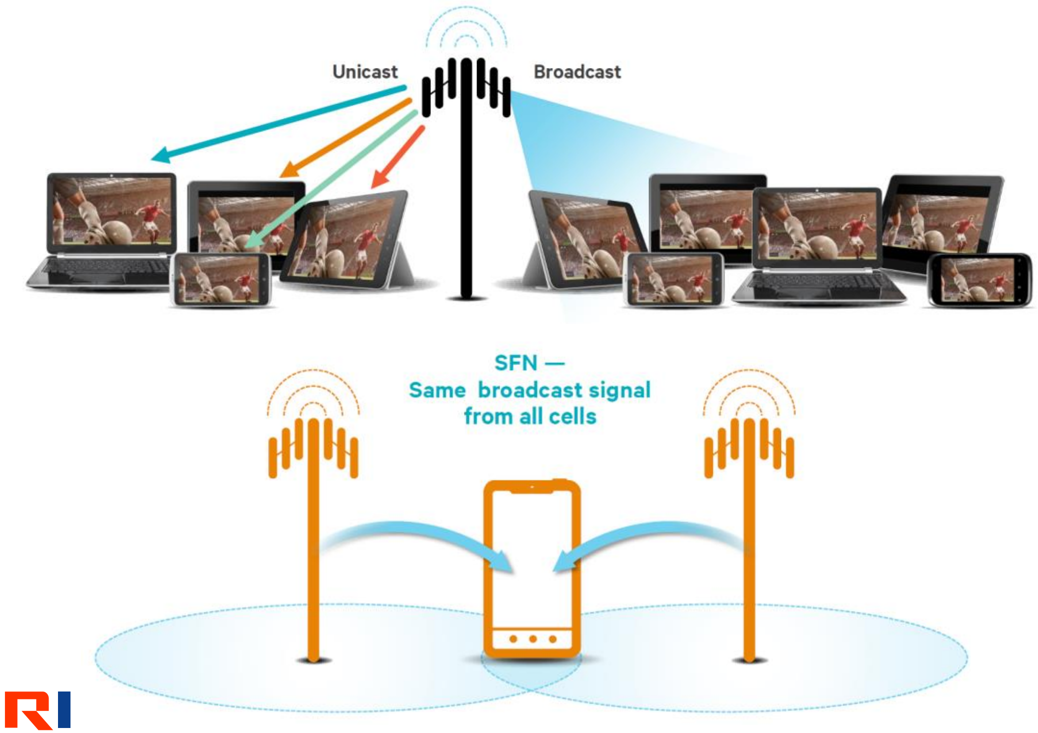
# MBMS: Broadcasting Services in 3GPP

- Broadcasting technologies in cellular-based mobile broadband (3GPP)
  - Starting from LPLT-based point-to-point service
  - Extended to HPHT-based infrastructure for a larger coverage
- MBMS (Multimedia Broadcast and Multicast Service ) features
  - Possible to efficiently deliver the same contents (i.e., popular contents: live news and sports) to massive subscribers based Point-to-multipoint (P-to-MP) versus Unicast
  - Possible to deliver the same contents to wider coverage due to SFN





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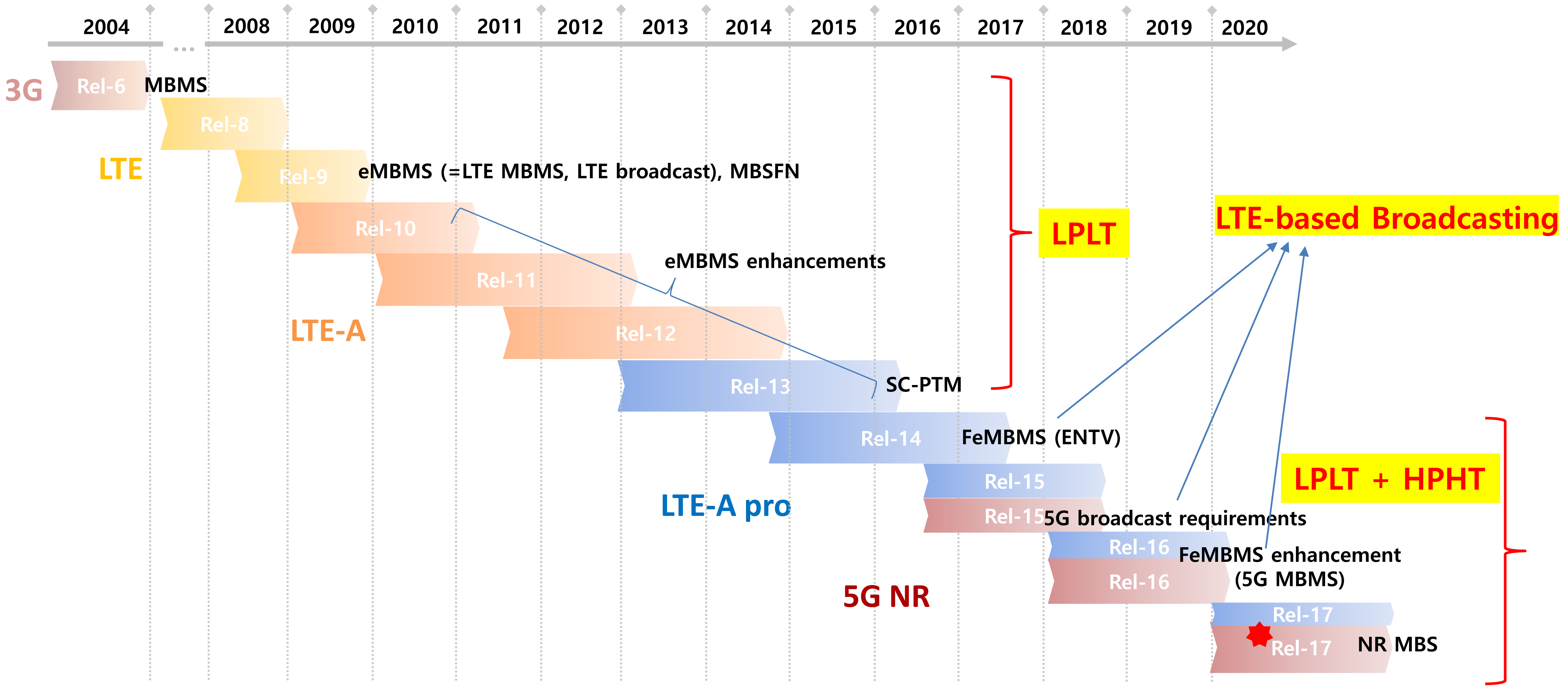
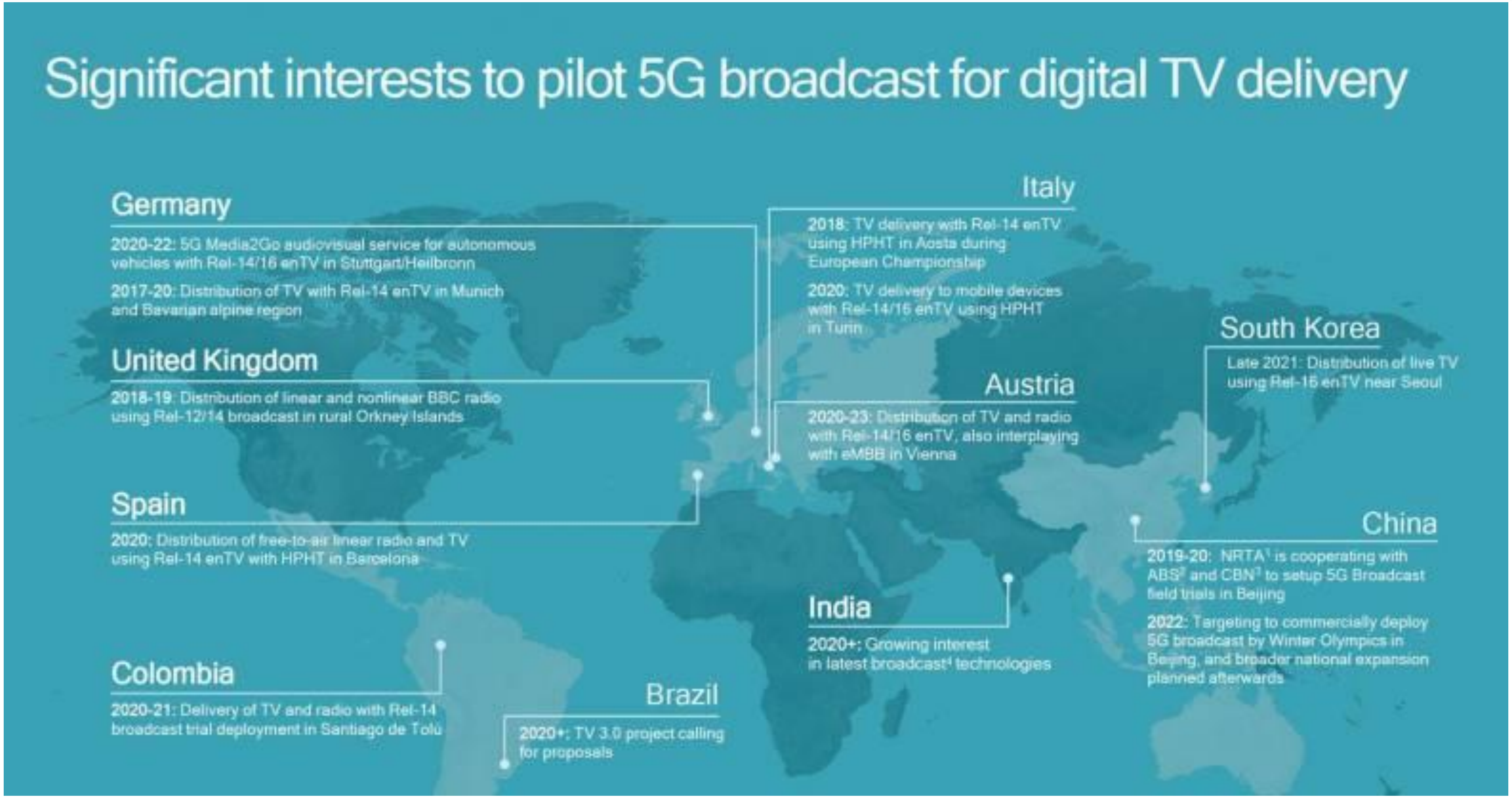
# MBMS: History from 3G to 5G



# MBMS: 5G-Broadcast Trials

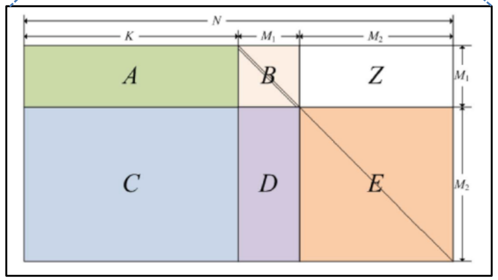



https://www.thebroadcastbridge.com/content/entry/18980/5g-broadcast-gains-momentum-with-field-trials

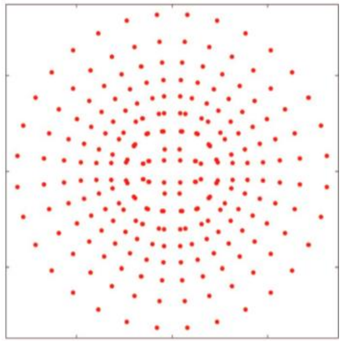
# BICM (Bit-Interleaved Coded Modulation)

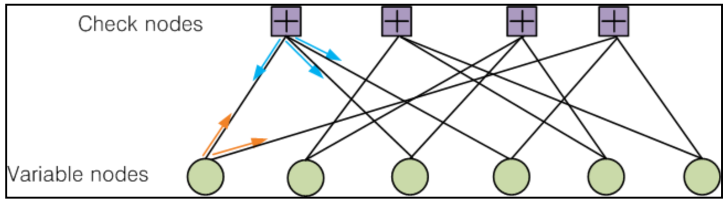
**ATSC 3.0**

## LDPC Code + NUC


[LDPC encoding]

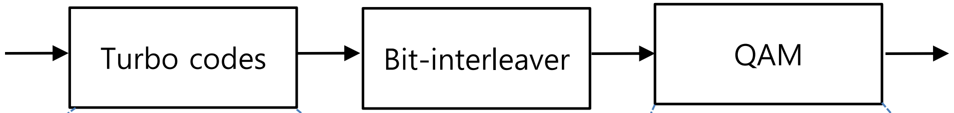


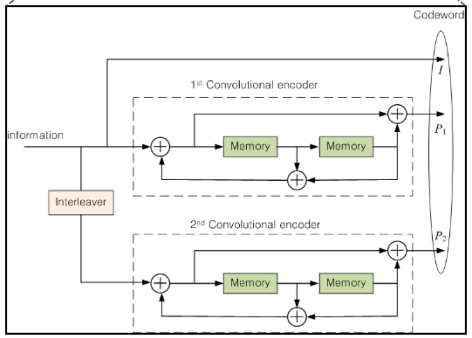



[LDPC decoding]

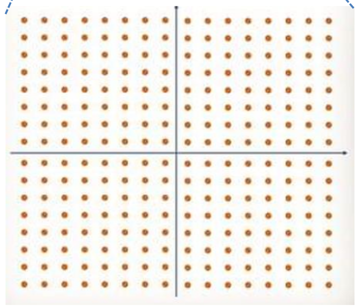
**FeMBMS**

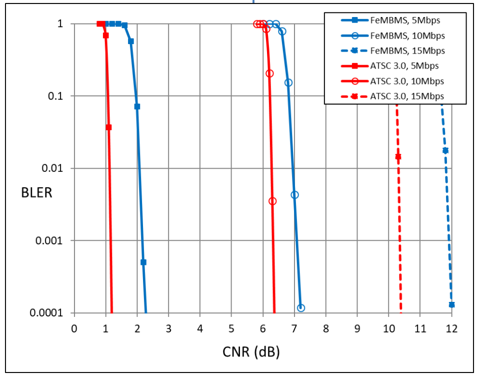
## Turbo Code + QAM



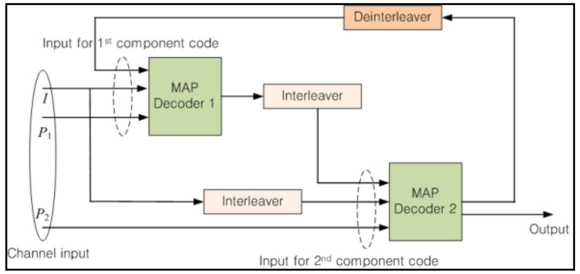




[Turbo encoding]






[BICM Performance]

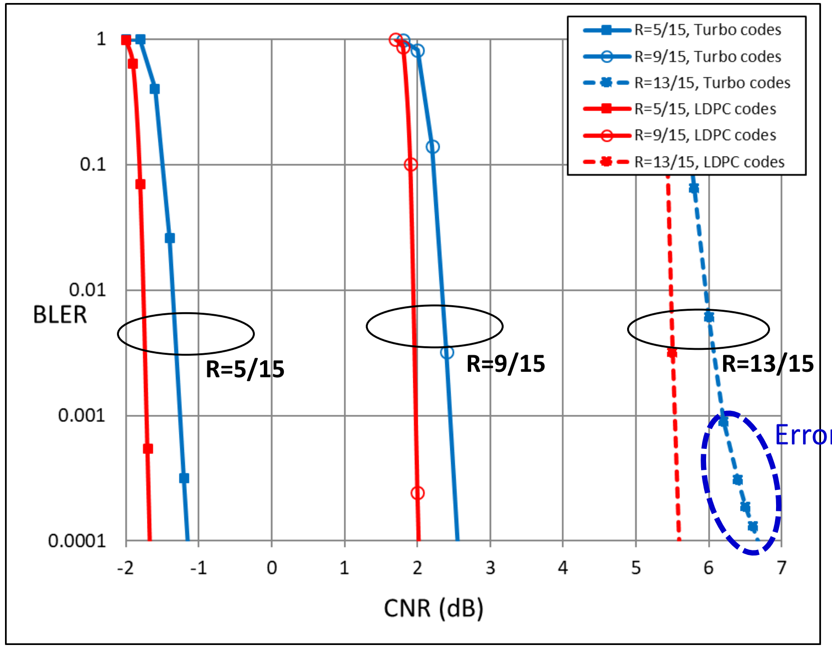



[Turbo decoding]

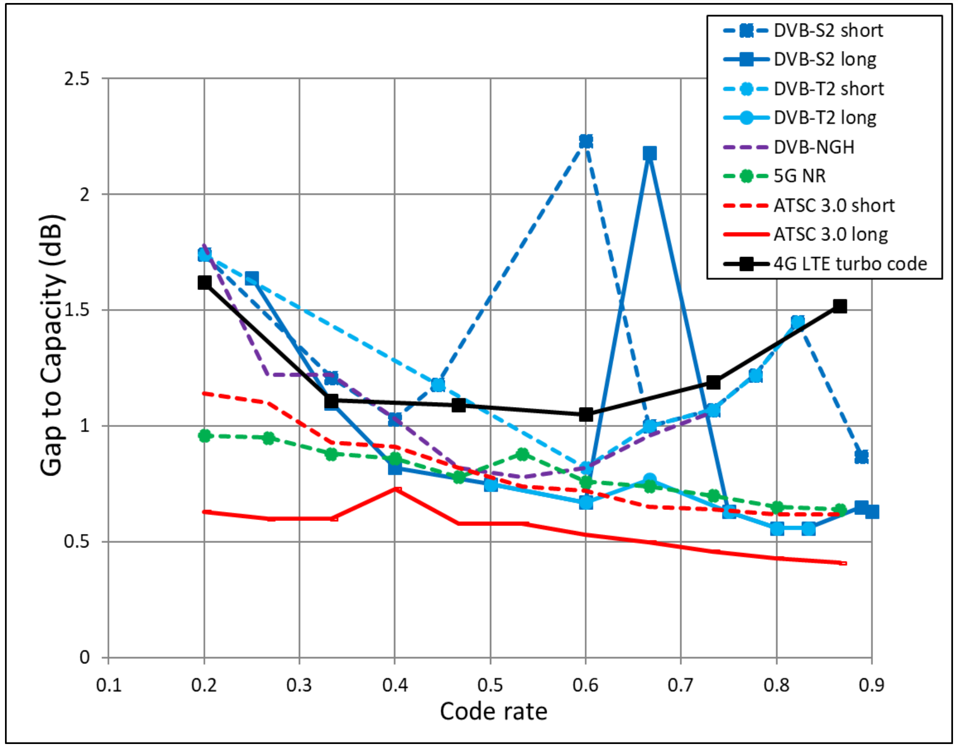
# BICM (Bit-Interleaved Coded Modulation)

## LDPC code vs Turbo code

| | ATSC 3.0 LDPC codes | FeMBMS Turbo codes |
|---|---|---|
| Optimized | Delicately optimized for each code rate | Originally for 1/3, Puncturing is used for variable code rates |
| Codeword length | Up to code bits 64,800 | Up to information bits 6144 |
| Error floor | Free | Sometimes, it happens |




[Performance: FeMBMS Turbo codes vs ATSC 3.0 LDPC codes]




[Performance: ATSC 3.0 LDPC codes vs other DTT standards]

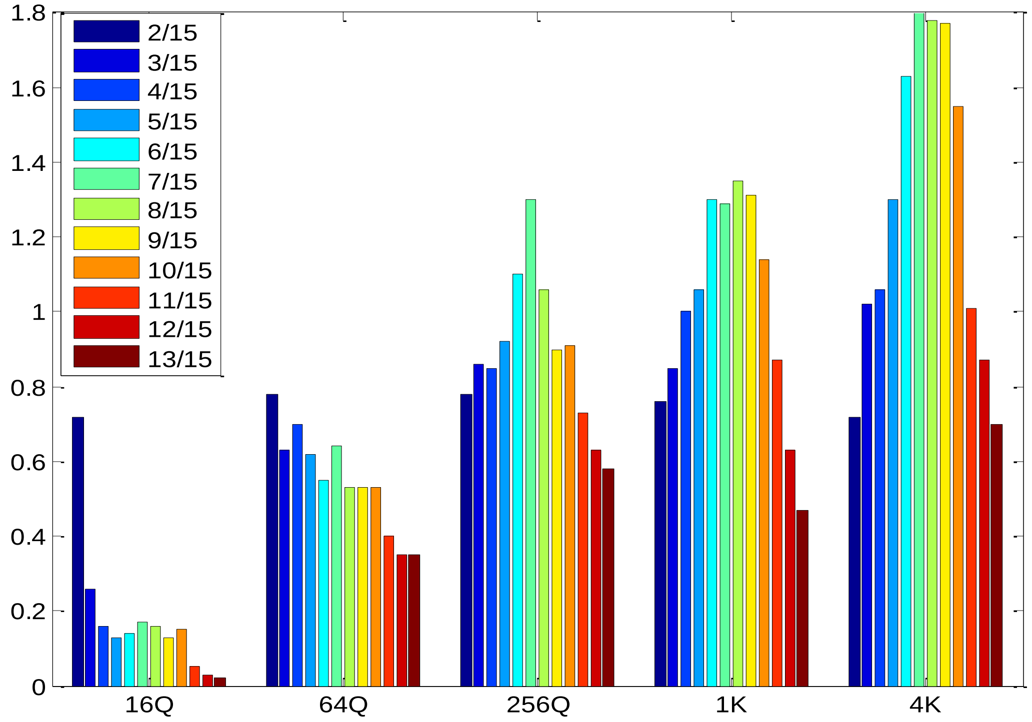
- ATSC 3.0 LDPC codes outperform other wireless broadcasting/communication standards
- ATSC 3.0 LDPC codes are less than 1 dB away from Shannon Capacity

K.-J. Kim *et al.*, "Low-Density Parity-Check Codes for ATSC 3.0." in *IEEE Trans. on Broadcasting*, vol. 62, no. 1, pp. 189-196, March 2016.

S.-K. Ahn *et al.*, "Comparison of Low-Density Parity-Check Codes in ATSC 3.0 and 5G Standards." in *IEEE Trans. on Broadcasting*, vol. 65, no. 3, pp. 489-495, Sept. 2019.

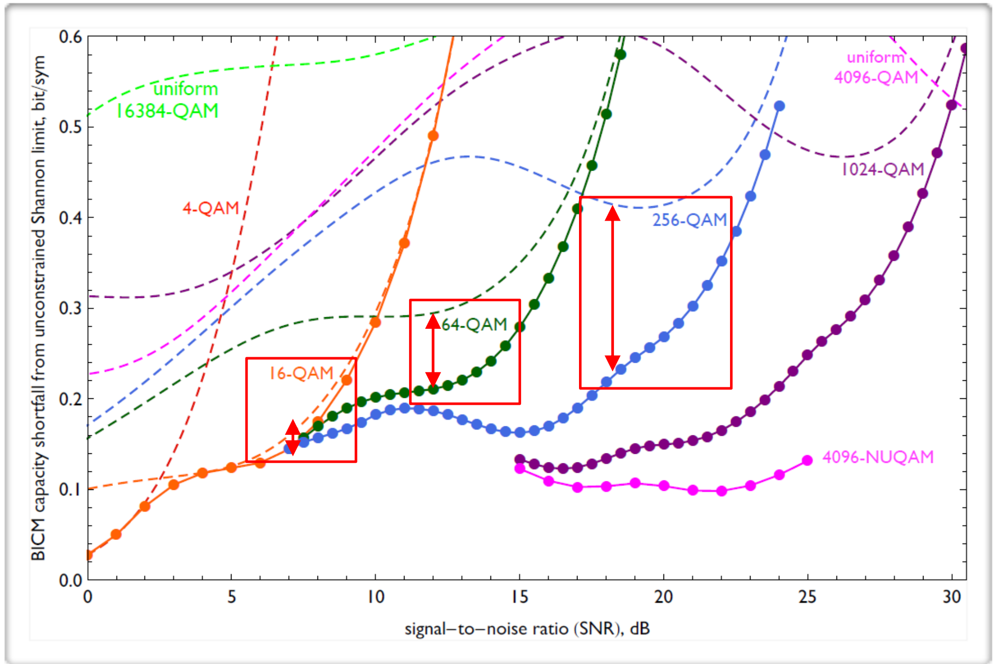
# BICM (Bit-Interleaved Coded Modulation)

## NUC vs QAM




[Performance: gain of ATSC 3.0 NUC over rectangular QAM]

- ATSC 3.0 NUCs outperform rectangular QAMs
- NUC gain increases when modulation order increases




[Shortfall of the BICM capacity from the Shannon capacity, NUC and QAM][1]

Performance of BICM chain is bounded by its BICM capacity.

➔ NUC is closer to BICM capacity than rectangular QAM

➔ NUC gain increases when modulation order increases

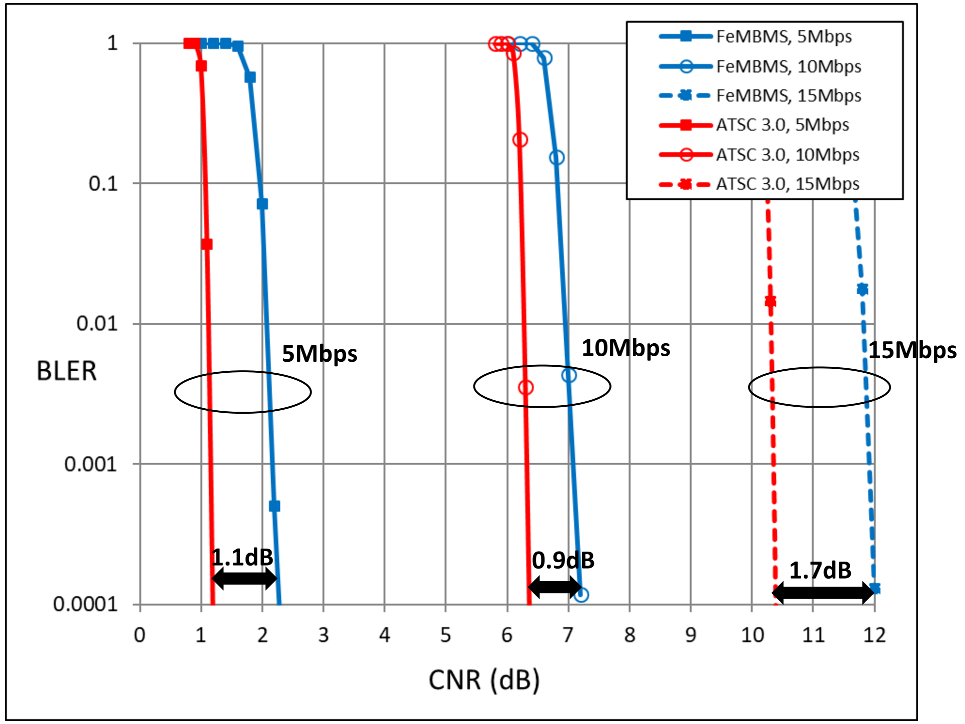
N. S. Loghin *et al*, "Non-Uniform Constellations for ATSC 3.0." in *IEEE Trans. on Broadcasting*, vol. 62, no. 1, pp. 197-203, March 2016.

[1] CM and BICM limits for rectangular constellations, Research & Development White Paper, BBC, 2013.

# Performance Comparison over AWGN channel

- **Evaluation over AWGN channel**

| | Required CNR (5Mbps) | Required CNR (10Mbps) | Required CNR (15Mbps) |
|---|---|---|---|
| ATSC 3.0 | 1.2dB | 6.4dB | 10.4dB |
| FeMBMS (Rel-16/17) | 2.3dB | 7.3dB | 12.1dB |
| **ATSC 3.0 gain over FeMBMS** | **1.1dB** | **0.9dB** | **1.7dB** |




[AWGN channel]

ATSC 3.0 has a better BICM (bit-interleaved coded modulation) efficiency than FeMBMS. In the AWGN channel, ATSC 3.0's latest LDPC codes and NUC (non-uniform constellation) combination provides around 1 – 2 dB gain compared to turbo codes and rectangular QAM of FeMBMS.

In terms of BICM, ATSC 3.0 is less than 1 dB away from Shannon Capacity.

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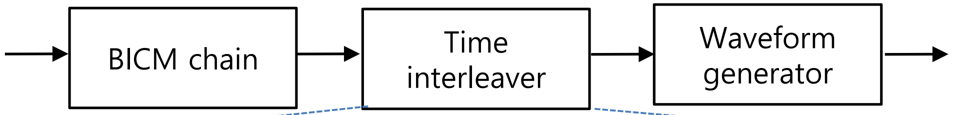
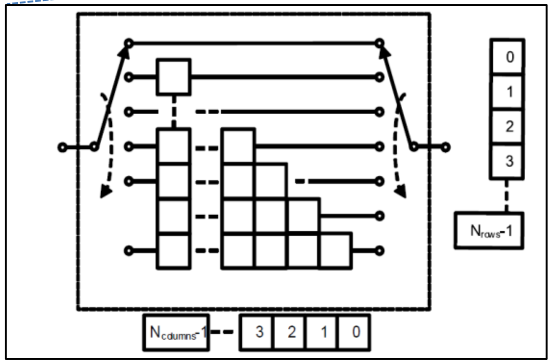
# Time Interleaver

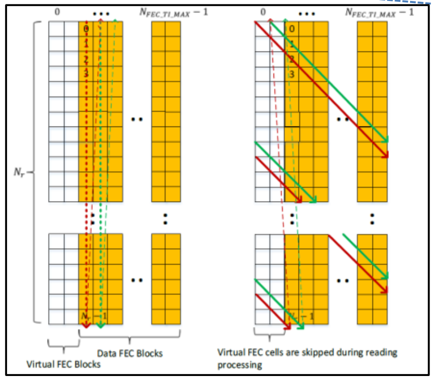
## ATSC 3.0 w. Time Interleaver

ATSC 3.0 PHY is designed to provide uniform performance under harsh mobile fading channels. → Time interleaver is an appropriate solution.




[Convolutional Time Interleaver]

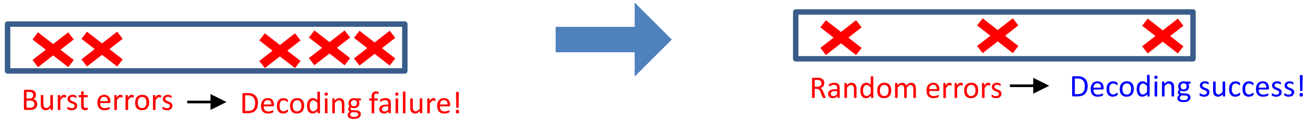



[Hybrid Time Interleaver]

ATSC 3.0's well-designed and optimized time-interleaver provides significant performance benefit over harsh fading environments.

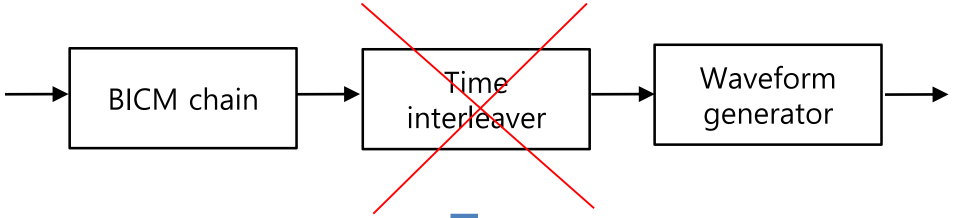
## Time Interleaver

Time interleaver spreads burst errors, caused by harsh fading channel, to random errors so that a receiver can make it decode successfully.

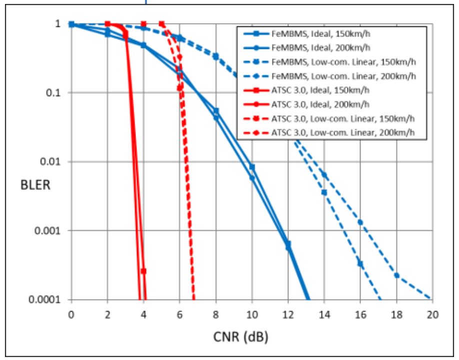



## FeMBMS w.o. Time Interleaver

LTE PHY (FeMBMS) is designed to minimize latency for supporting latency requirements of unicast transmission. → Time interleaver is not allowed in LTE PHY layer.

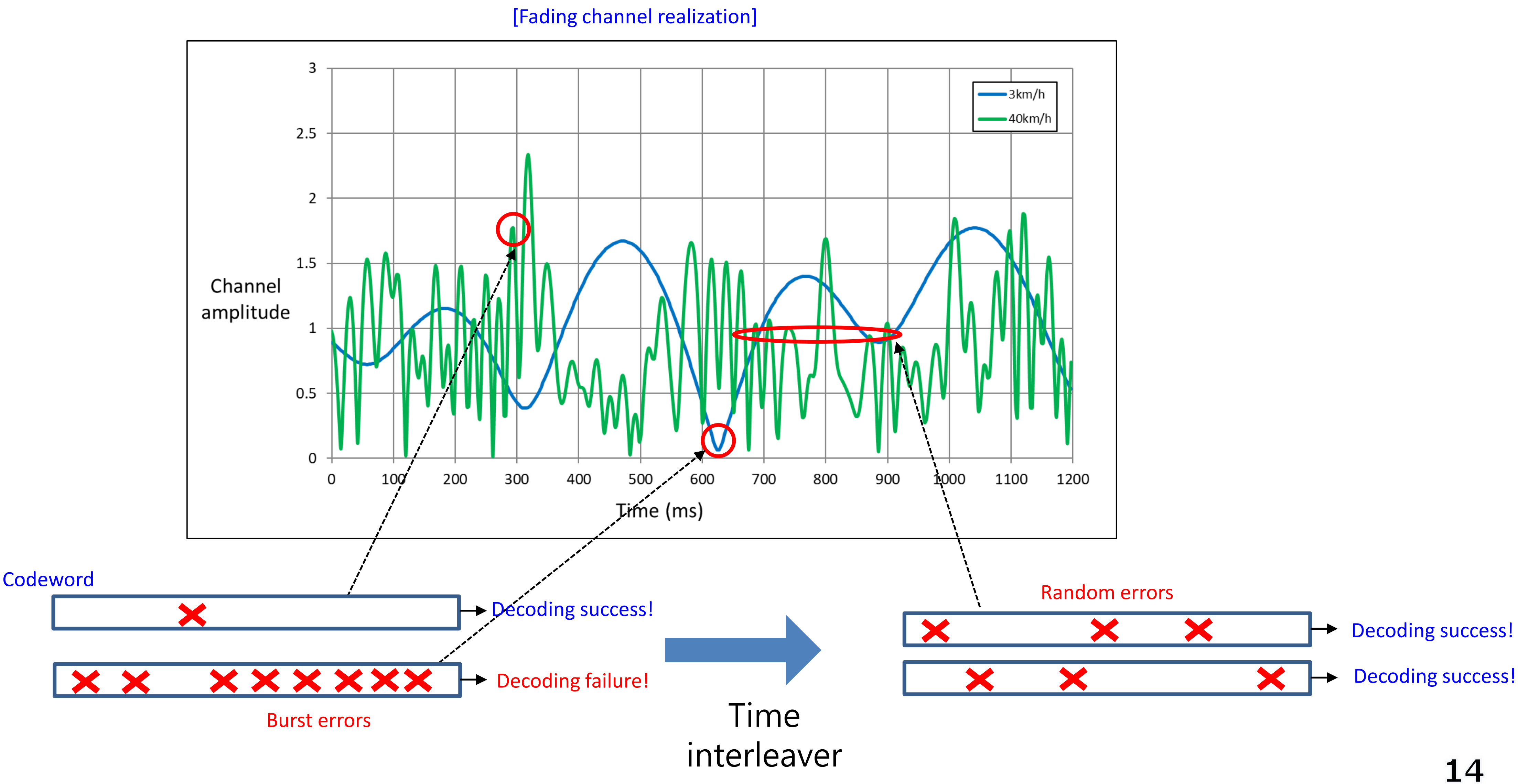



FeMBMS doesn't have a time interleaver function to handle harsh channel fading.



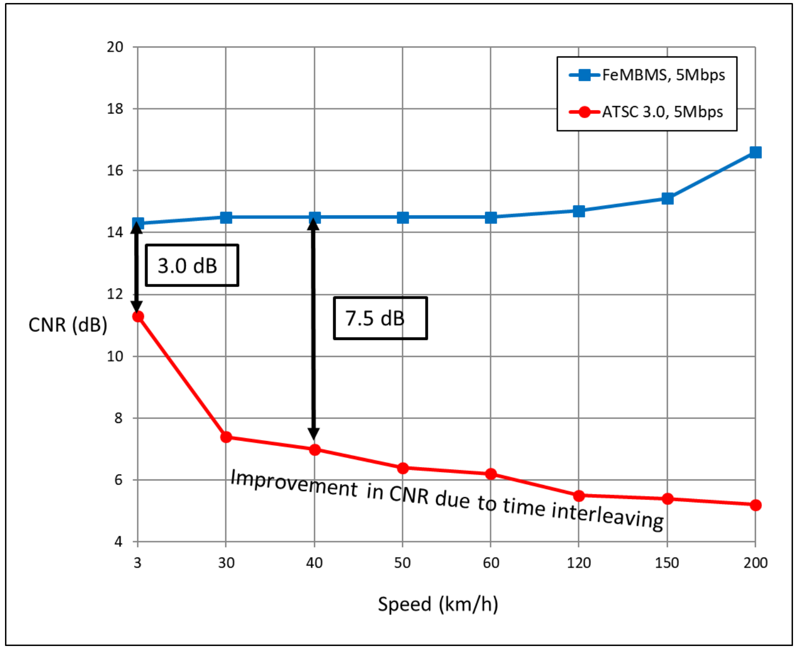

[Fading Performance]

# Time Interleaver

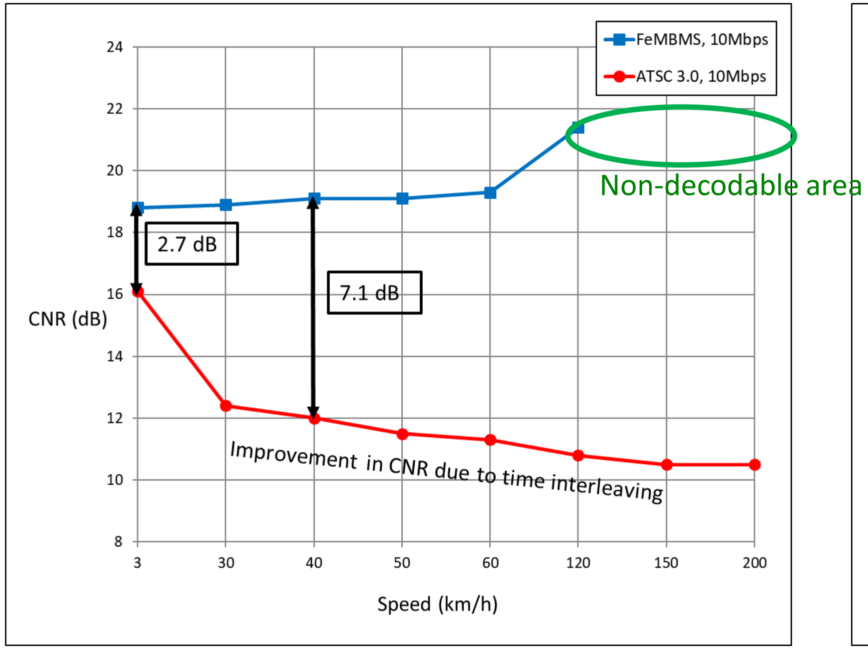


# Time Interleaver Effect over India-Urban channel

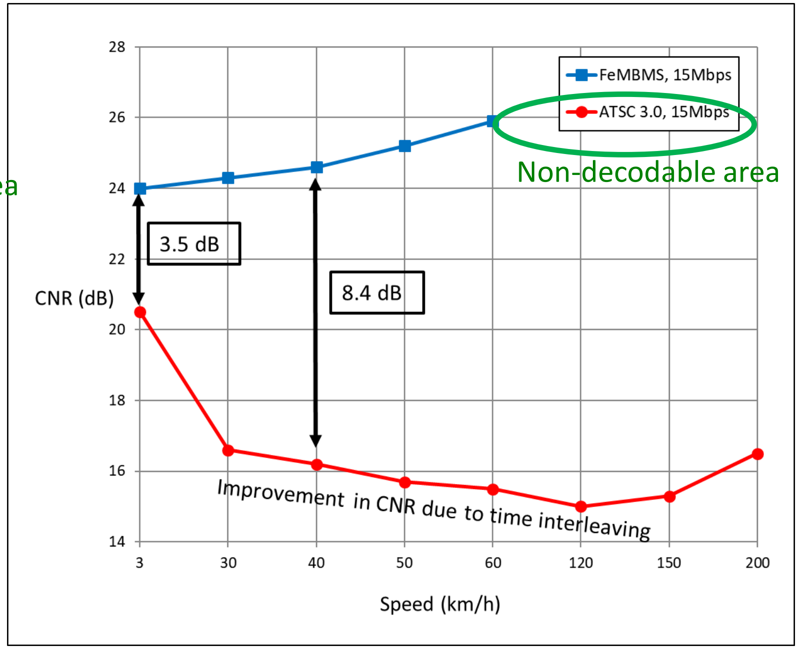
- **Advantage for ATSC 3.0 compared to FeMBMS (Rel-16/17)**




[5Mbps – From 3km/h to 200km/h]




[10Mbps – From 3km/h to 200km/h]

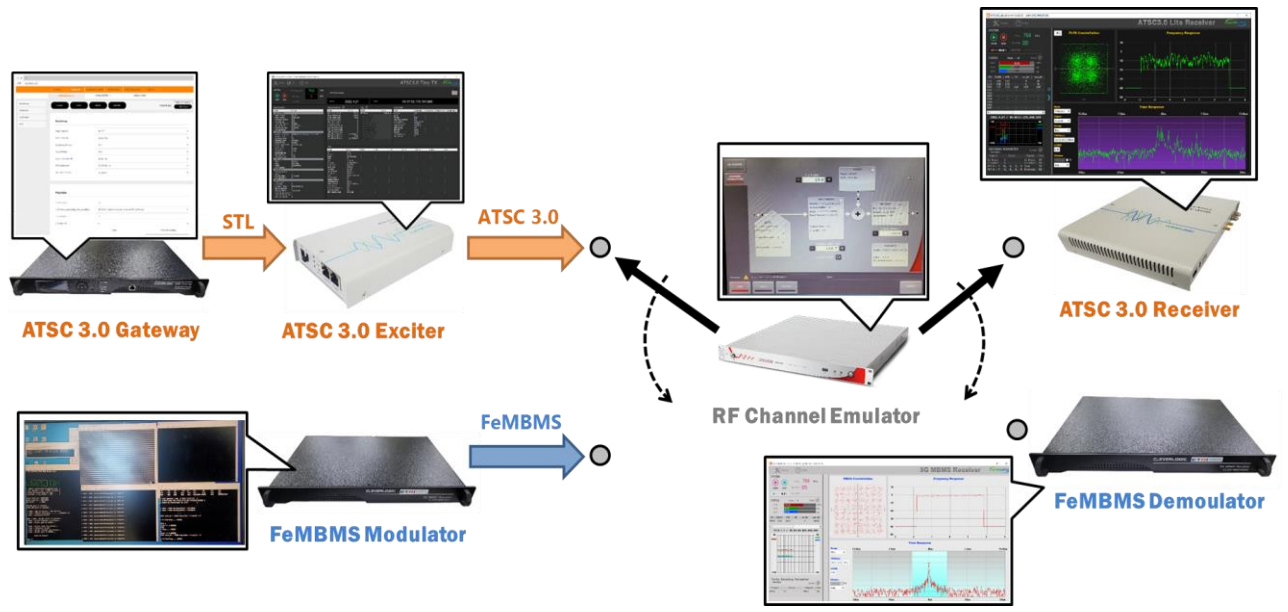



[15Mbps – From 3km/h to 200km/h]

| Data rate / Mobility | ATSC 3.0 gain over FeMBMS (Rel-16/17) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3km/h | 30km/h | 40km/h | 50km/h | 60km/h | 120km/h | 150km/h | 200km/h |
| 5Mbps | 3.0 dB | 7.1 dB | 7.5 dB | 8.2 dB | 8.3 dB | 9.2 dB | 9.7 dB | 11.4 dB |
| 10Mbps | 2.7 dB | 6.6 dB | 7.1 dB | 7.6 dB | 8.0 dB | 10.7 dB | FeMBMS non-decodable | |
| 15Mbps | 3.5 dB | 7.7 dB | 8.4 dB | 9.5 dB | 10.4 dB | FeMBMS non-decodable | | |

# Comparison of ATSC 3.0 vs. 5G Broadcast (Rel-16/17)

[HW-based Laboratory Test] ATSC 3.0 Subframe vs. 5G Broadcast PMCH ➔ 6MHz BW, 768MHz CF, India-Urban/TU-6 channel




[HW-based Laboratory Environment]

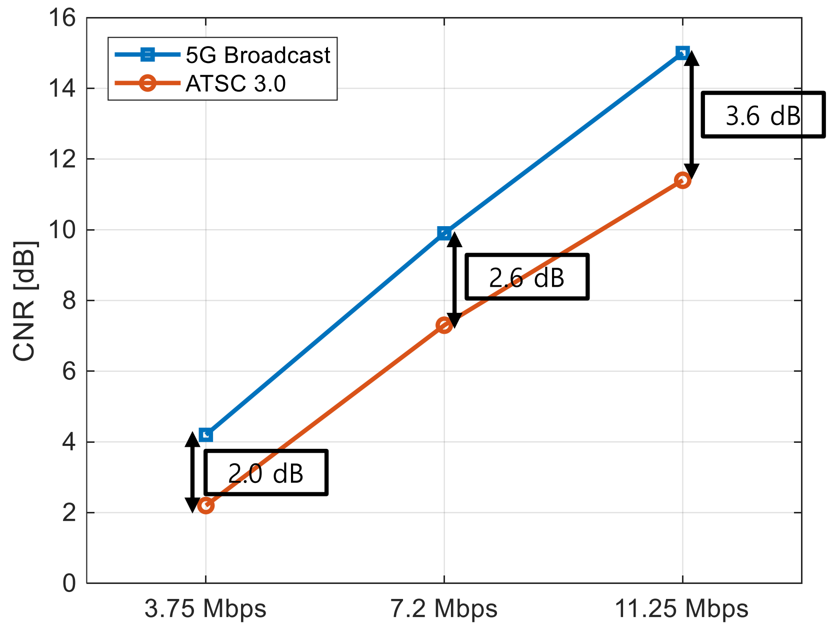
| Configuration / Mobility | | ATSC 3.0 gain over 5G Broadcast (Rel-16/17) | | |
|---|---|---|---|---|
| | | 3.75 Mbps | 7.5 Mbps | 11.25 Mbps |
| India-Urban | 3km/h | 8.0 dB | 5G Broadcast non-decodable | 5G Broadcast non-decodable |
| | 40km/h | 9.8 dB | 9.5 dB | 5G Broadcast non-decodable |
| TU-6 | 3km/h | 4.5 dB | 6.3 dB | 5G Broadcast non-decodable |
| | 40km/h | 10.3 dB | 9.7 dB | 5G Broadcast non-decodable |

[Performance Comparison between ATSC 3.0 and 5G Broadcast]

# Comparison of ATSC 3.0 vs. 5G Broadcast (Rel-16/17)

[HW-based Laboratory Test] ATSC 3.0 Subframe vs. 5G Broadcast PMCH ➔ 6MHz BW, 768MHz CF, AWGN/India-Urban/TU-6 channel

[AWGN]




[India-Urban/TU-6]

| Configuration / Mobility | ATSC 3.0 gain over 5G Broadcast (Rel-16/17) | | | |
|---|---|---|---|---|
| | India-Urban | | TU-6 | |
| | 3km/h | 40km/h | 3km/h | 40km/h |
| 3.75 Mbps | 8.0 dB | 9.8 dB | 4.5 dB | 10.3 dB |
| 7.5 Mbps | 5G Broadcast non-decodable | 9.5 dB | 6.3 dB | 9.7 dB |
| 11.25 Mbps | 5G Broadcast non-decodable | 5G Broadcast non-decodable | 5G Broadcast non-decodable | 5G Broadcast non-decodable |

# Comparison of ATSC 3.0 vs. 5G Broadcast (Rel-16/17)

- Transmitter Facilities for ATSC 3.0 and 5G-MBMS Field Trial in 2022

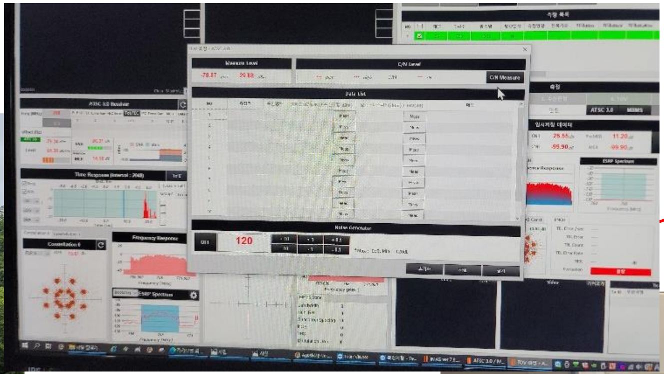
<Building & Tower >

<Gateway & Tx Controller>


< 5G MBMS and ATSC 3.0 Transmitter >
Center Frequency : 768MHz (BW:6MHz)
Transmission power : 100W

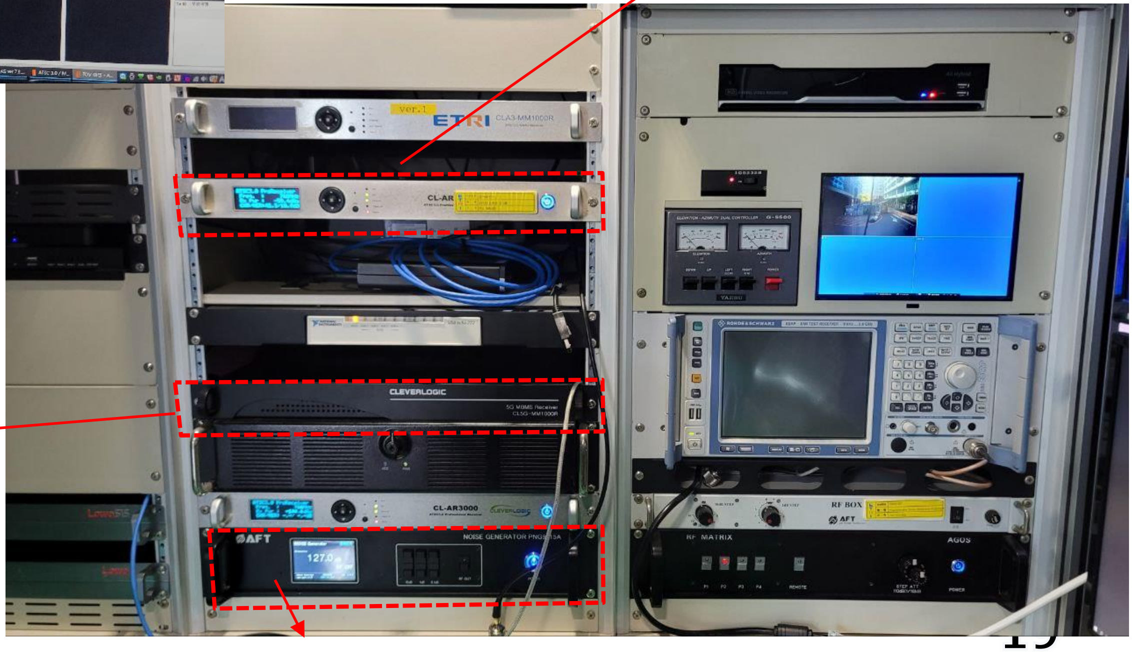
# Comparison of ATSC 3.0 vs. 5G Broadcast (Rel-16/17)

- Receiver (Test Vehicle) Facilities for ATSC 3.0 and 5G-MBMS Field Trial in 2022
  - For both fixed and mobile reception

ATSC 3.0 and 5G-MBMS measurement system

ATSC 3.0 receiver



5G-MBMS receiver

Noise Signal Generator

# Comparison of ATSC 3.0 vs. 5G Broadcast (Rel-16/17)

6MHz is used (instead of 8MHz)

## ATSC 3.0

| Common Configuration (ATSC 3.0) | | |
|---|---|---|
| Center frequency | | 768 MHz |
| Bandwidth | | 6MHz |
| Common parameters | FFT size | 8192 |
| | Guard interval | GI7_2048 (222.22 us) |
| Preamble parameters | Pilot Pattern | SP_Dx = 3 |
| | Signaling Protection | L1-Basic/Detail mode 1 |
| Payload OFDM parameters | Pilot pattern | SP3_2 |
| | # of payload symbols | 222 |
| | Time interleaver | CTI with a depth of 1024 |
| | Frequency interleaver | On |
| Frame length | | 250.8889 ms |

| | Configuration 1 | Configuration 2 | Configuration 3 |
|---|---|---|---|
| Outer code | 8/15-LDPC (64800) | 8/15-LDPC (64800) | 8/15-LDPC (64800) |
| Constellation | QPSK | 16-NUC | 64-NUC |
| Data rate | 4.03 Mbps | 8.06 Mbps | 12.09 Mbps |

## 5G-MBMS

| Common Configuration (5G-MBMS) | |
|---|---|
| Center frequency | 768 MHz |
| Bandwidth | 6MHz (30RBs) |
| FFT size | 12288 |
| Guard interval | 200us |
| Pilot pattern | SP3_2 |
| Subcarrier spacing | 1.25KHz |
| MCS table | Table 7.1.7.1-1 (TS 36.213)<br>Max 64-QAM table |

| | Configuration 1 | Configuration 2 | Configuration 3 |
|---|---|---|---|
| MCS index | 8 | 14 | 20 |
| TBS | 4264 | 7736 | 11832 |
| Code rate | 0.58 | 0.54 | 0.553 |
| Constellation | QPSK | 16-QAM | 64-QAM |
| Data rate | 4.16 Mbps | 7.54 Mbps | 11.54 Mbps |

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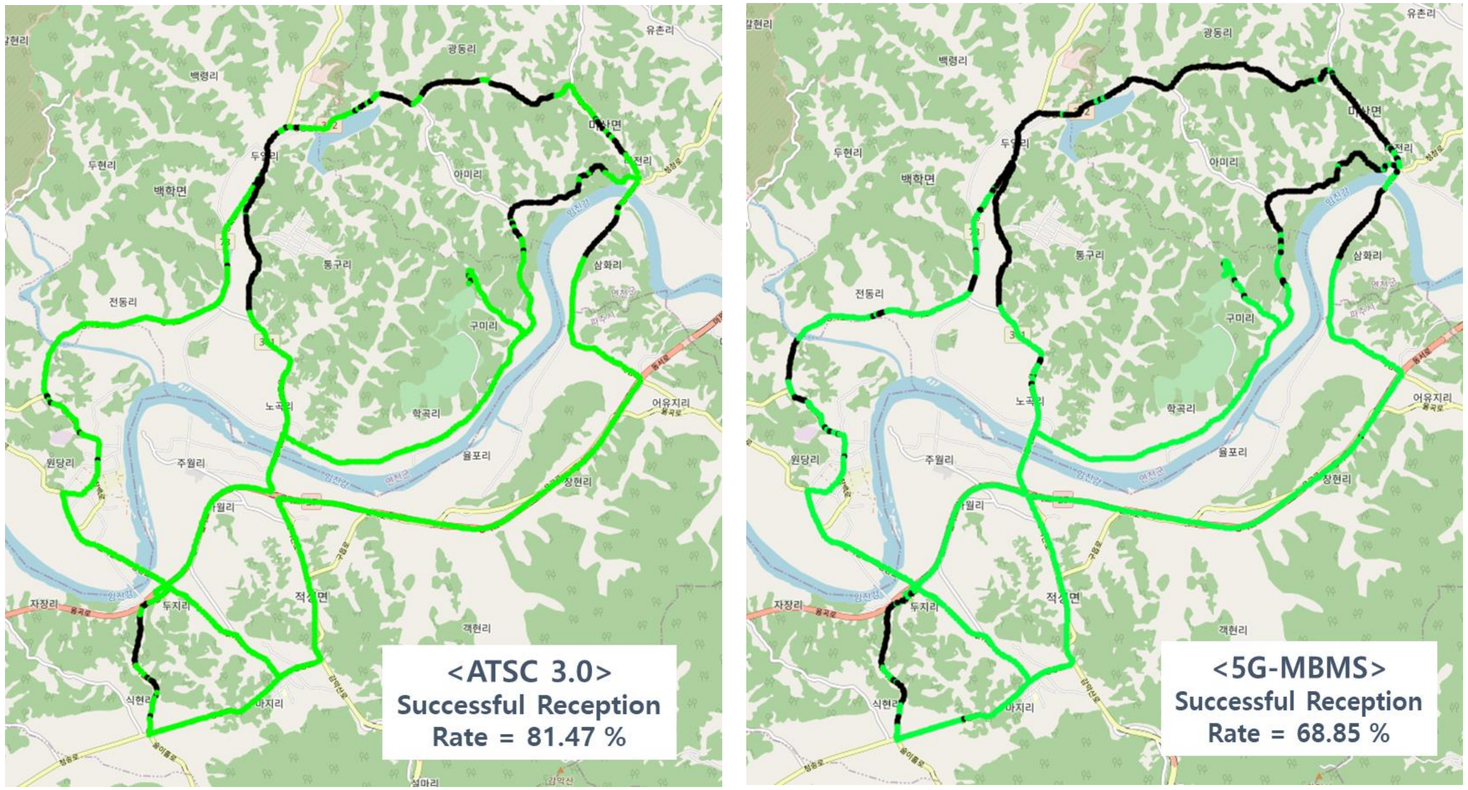
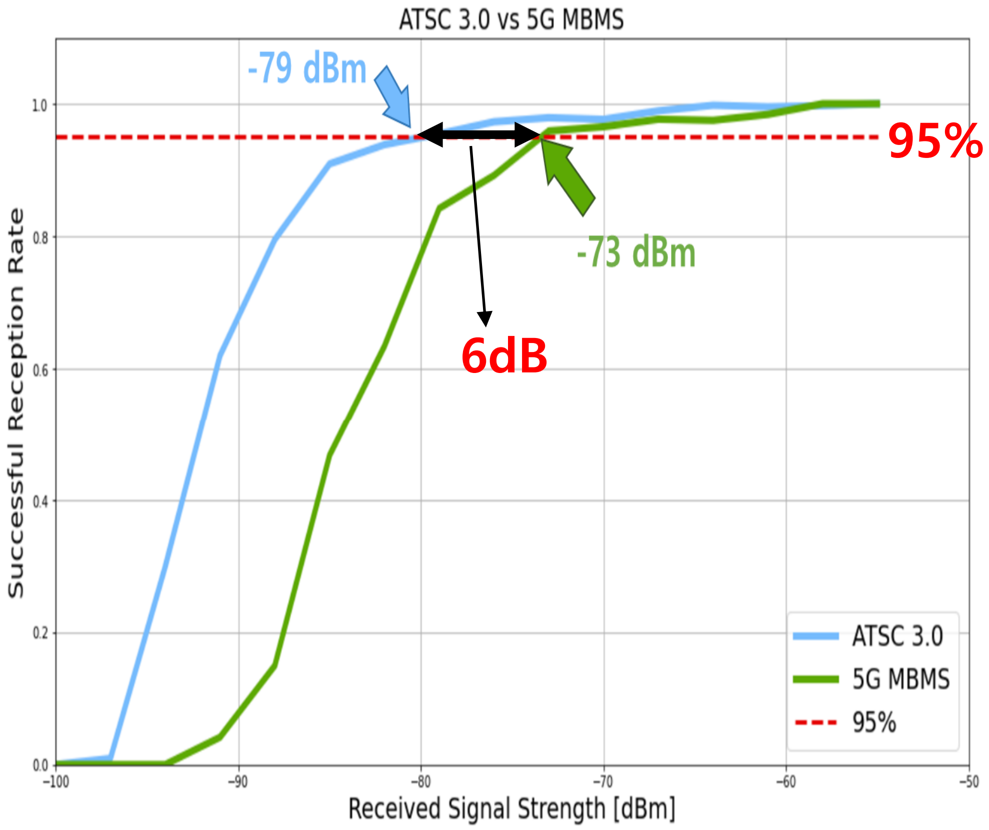
# Comparison of ATSC 3.0 vs. 5G Broadcast (Rel-16/17)

[Field Test] ATSC 3.0 Subframe vs. 5G Broadcast PMCH ➔ 6MHz BW, 768MHz CF, 5Mbps



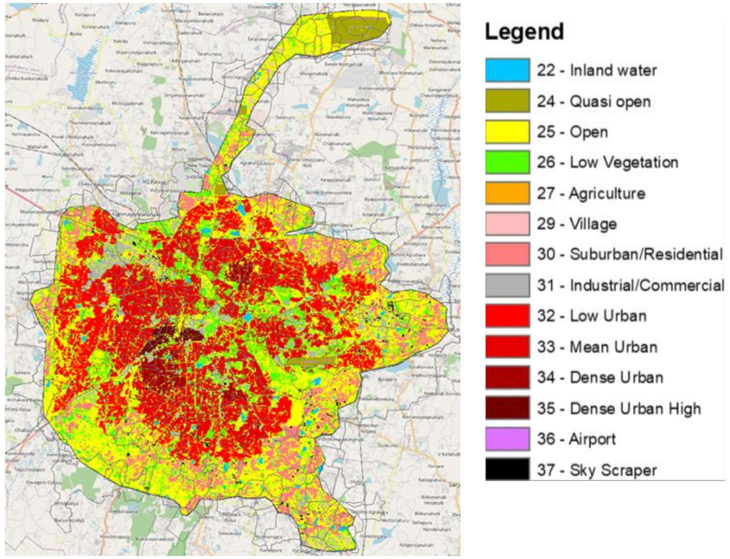

[Reception Success or Failure @ 5Mbps]




[ESR5 @ 5Mbps]

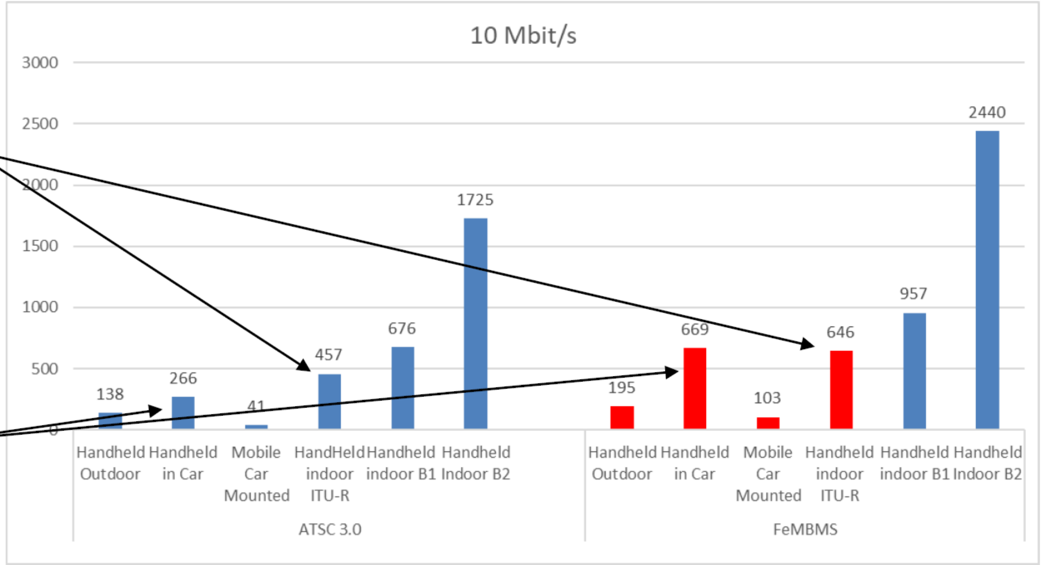
# Network Cost Comparison

- **System eligibility – Network cost**
  - ✓ ATSC 3.0 and FeMBMS physical-layers are compared in terms of network cost.
  - ✓ Network expense (CAPEX & OPEX) can be abstracted in terms of the number of operational towers.




[Considered service area in Bangalore, India]

- Results for 10 Mbit/s presented here
- For Handheld indoor (ITU-R) the number of requited sites increase from 457 to 646 (40% increase) ATSC 3.0 vs FeMBMS
- For Handheld in Car reception the increase is about 150 % (266 to 669 sites)



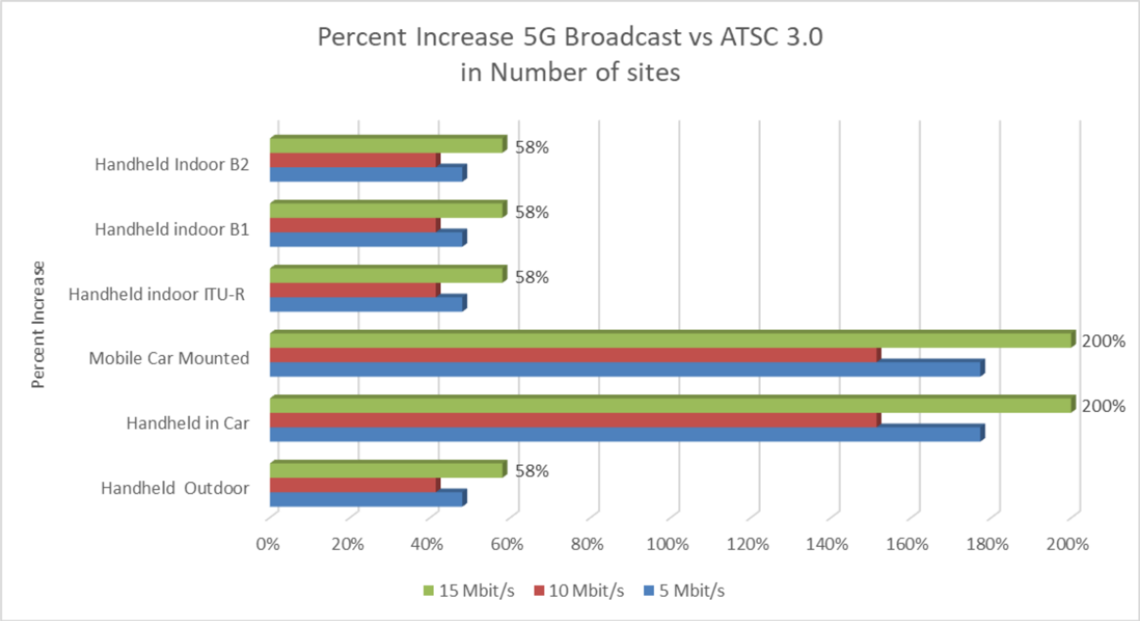

[Theoretical Study: Bangalore, Results]

These results are from Progira's network simulation

# Network Cost Comparison

- **System eligibility – Network cost**
  - ✓ Given the target service area and QoS, ATSC 3.0 is more efficient solution in terms of network operation than FeMBMS.

- For handheld indoor reception the FeMBMS (5G Broadcast) will require 40-60% more sites
- For mobile reception the increase in number of sites required for FeMBMS is 140-200%. The reason for the large difference is lack of that time interleaving in 5G Broadcast Release 16/17
- In General 5 dB difference in required C/N will double number of required sites!




[Theoretical Study: Considerations, Summary]

PROGIRA

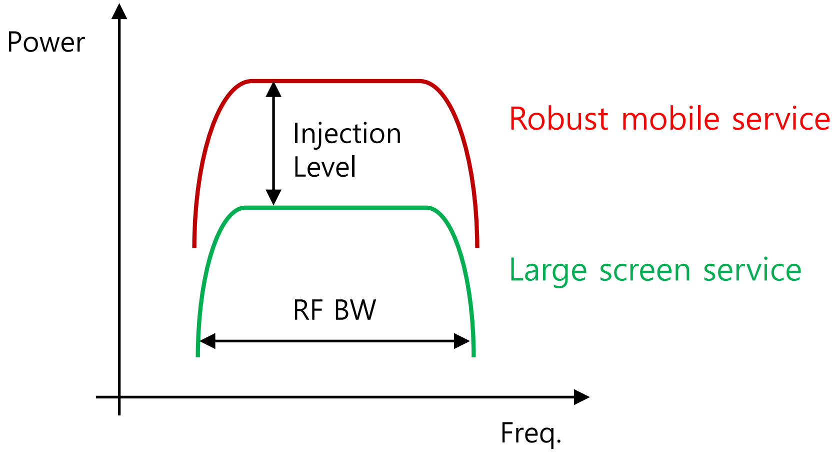
These results are from Progira's network simulation

# Layered Division Multiplexing (LDM)

**Conventional transport vehicle: single-decker bus.**

**LDM is like a double-decker bus, more capacity with the same foot print (bandwidth)**

**Possible for future extension!!**




< LDM signal configuration >

## LDM key features

- Different services with different robustness are superimposed with different power
- 100% of RF bandwidth & 100% of time are fully used for both robust mobile service & large screen service
- LDM has significant performance gain (3 to 9 dB) over a traditional TDM/FDM schemes [ref]
- Commercialized ATSC 3.0 TVs support LDM technology

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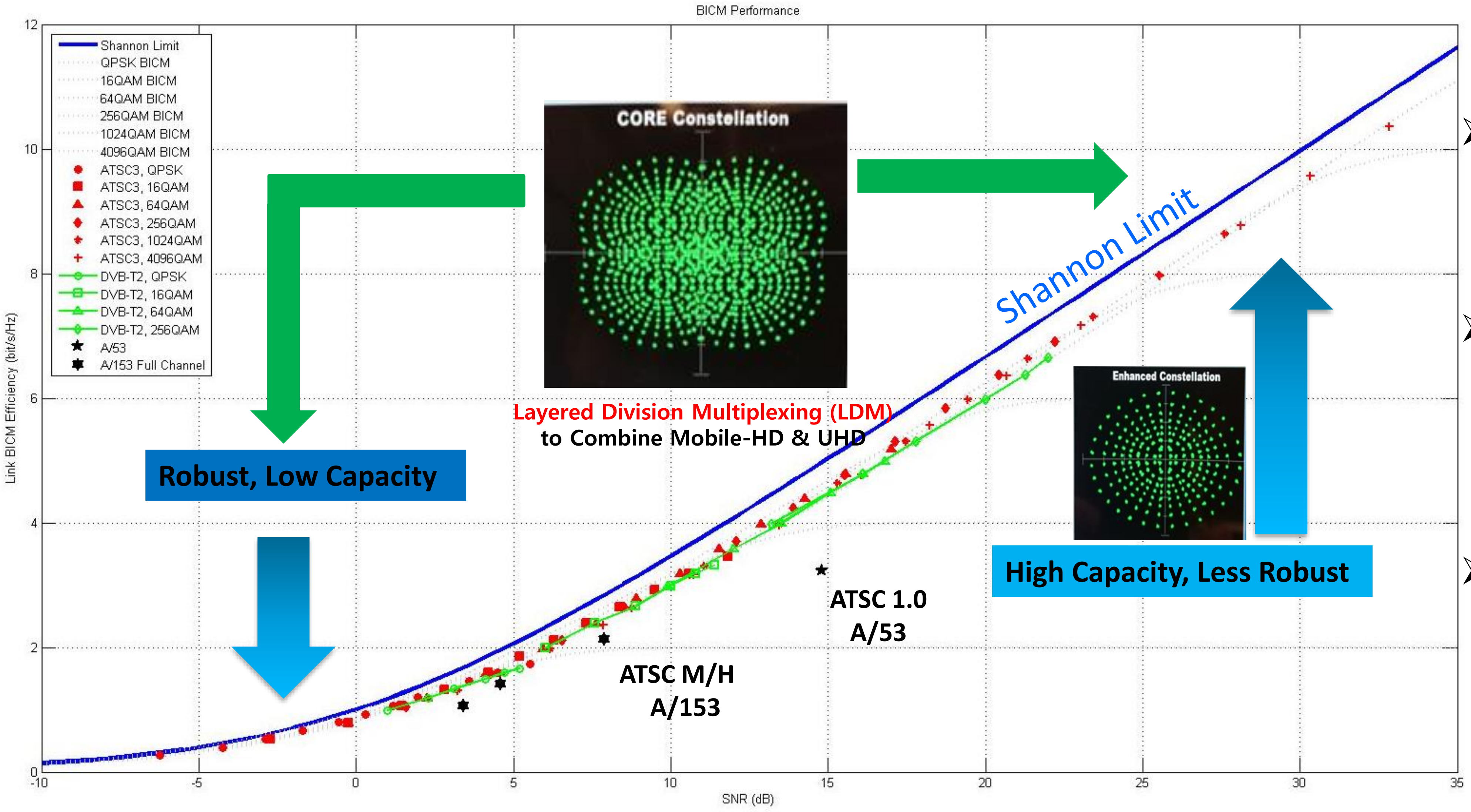
[ref#1] S-I. Park *et al.*, "Low Complexity Layered Division Multiplexing for ATSC 3.0," in *IEEE Trans. on Broadcasting*, vol. 62, no. 1, pp. 233-243, March 2016.
[ref#2] S-I. Park *et al.*, "Field Comparison Tests of LDM and TDM in ATSC 3.0," in *IEEE Trans. on Broadcasting*, vol. 64, no. 3, pp. 637-647, Sept. 2018.

# Shannon Capacity

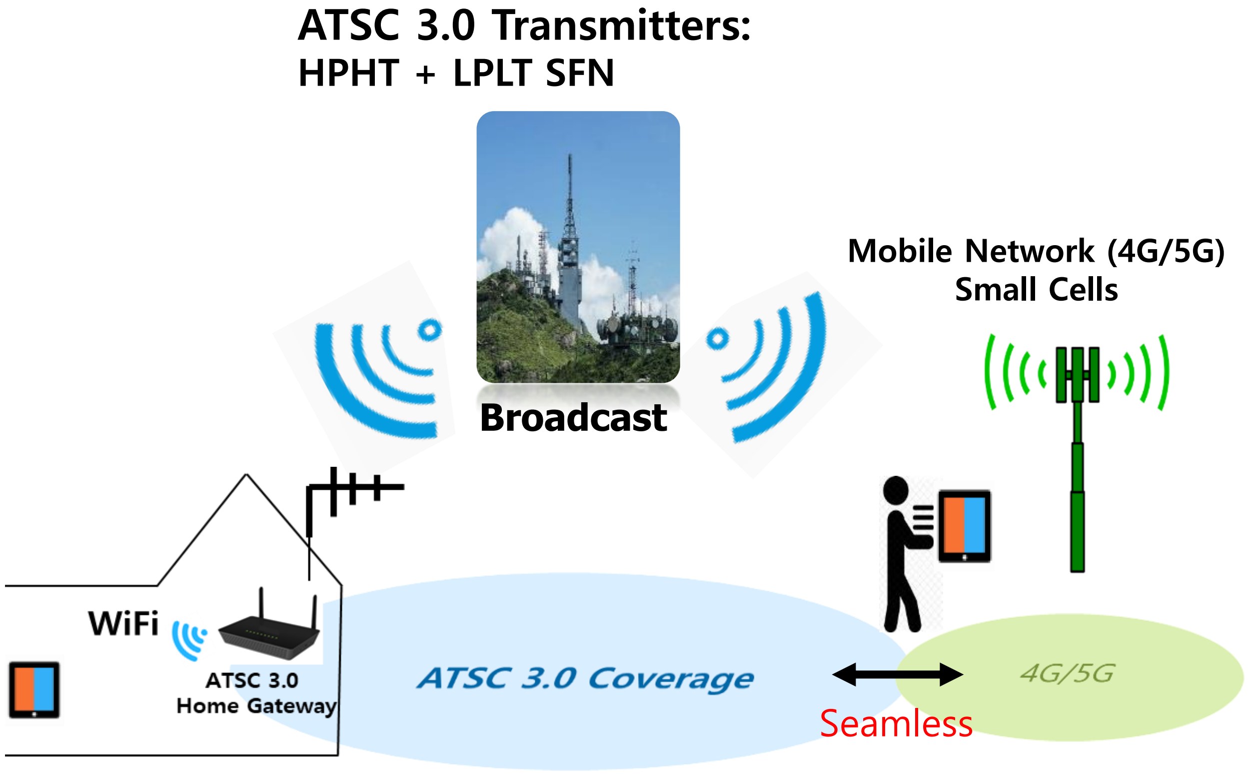



- **Flexibility**: provide large range of operating modes
- **Robustness**: for mobile or deep indoor reception (~ -6 dB SNR)
- **Spectral efficiency:** better efficiency when services are multiplexed ➔ LDM, SHVC

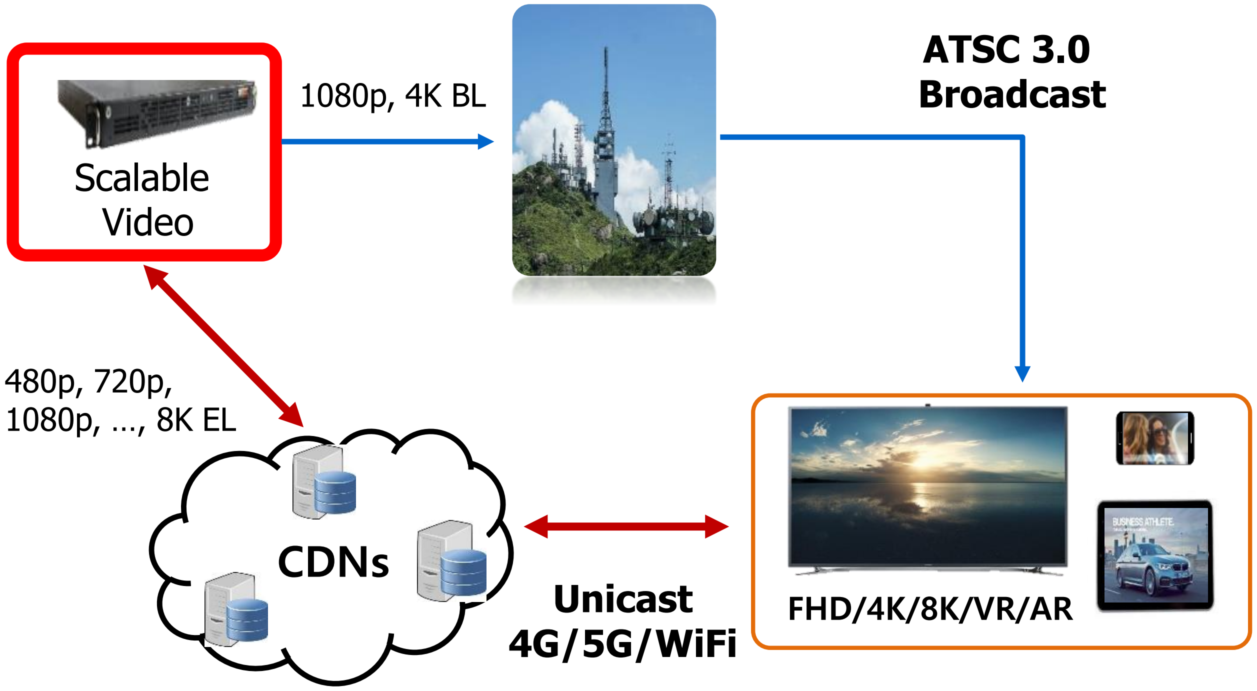
# ATSC 3.0 Broadcast Convergence with Broadband

- **ATSC 3.0 IP-Based Broadcast ➔ feasible to cooperate/converge with Broadband (4G/5G/WiFi and others)**

## Seamless Experience between BC and BB




## Better Quality through BC + BB



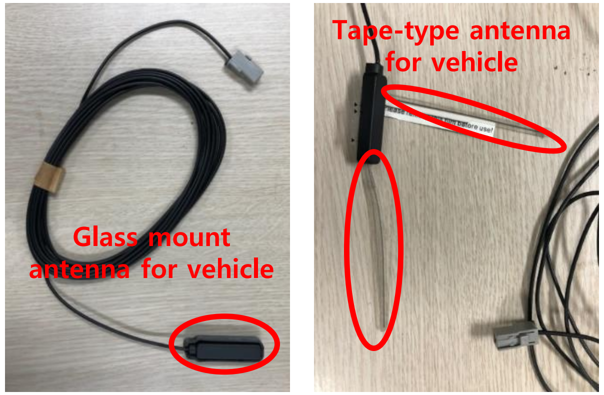

- ✓ ATSC 3.0 Broadcast (HPHT or HPHT/LPLT) takes dominant consumption of A/V traffic
  - ✓ Broadband can be supplemented (interactivity, hybrid, coverage extension) thru Unicast
- ✓ Seamless Experience & Better Quality ➔ Viewers don't care about network technology and prefer low-cost (or free) network

# Direct-to-Mobile in Korea

## Smart-phone demonstration


- **DTM live demonstration** in South Korea on March 2022
  - Public and official demos driven by **KBS**
  - Technical support by ETRI and SBG
- Smartphone with built-in chipset on-board, "**MarkONE**"
  - Supervised by **SBG**, chipset manufactured by **Saankhya Labs**

## Commercialized vehicle receiver




Commercialized vehicle antenna

Commercialized vehicle receiver

Korea's major car manufacture will launch ATSC 3.0-ready vehicles in the US and Korea in 2024.

ETRI

# Summary of the Benefits of ATSC 3.0

1. **Convergence with Broadband**
   - ✓ ATSC 3.0 IP-based broadcast makes it possible to cooperate/converge with Broadband (4G/5G/Wi-Fi and others)
   - ✓ 'Seamless Experience' & 'Better Quality' are the commercialized examples of BC/BB convergence
2. **BICM chain**
   - ✓ Well-designed and-optimized structure provides superior performance than any other DTT standard thanks to the superiority of the latest LDPC code and NUC.
   - ✓ ATSC 3.0 is less than 1 dB away from Shannon Capacity in terms of BICM.
3. **Time interleaver**
   - ✓ Time diversity makes ATSC 3.0 have stable performance in various fast fading channels.
   - ✓ Comparing FeMBMS not having time-interleaver, ATSC 3.0 has a 3 dB to 11 dB performance advantage depending on vehicle speeds.
4. **Flexibility in terms of numerology**
   - ✓ ATSC 3.0 provides excellent flexibility for selecting various combinations of guard interval, FFT size, and pilot patterns, depending on the geographical size of the broadcasting network and service requirements.
   - ✓ However, in FeMBMS, guard interval, FFT size, and pilot pattern are fixed for given OFDM numerology.
5. **Layered Division Multiplexing**
   - ✓ Unique & differentiated technology (world 1st commercialized non-orthogonal multiplexing technology, a.k.a NOMA in 3GPP)
   - ✓ LDM provides significant performance gain (3 to 9 dB) over a traditional TDM/FDM schemes.