BROADCASTING THE FUTURE

Inter-Tower Communications Network (ITCN) for NextGEN TV

Humber Institute NextGEN TV Open House

ATSC Tower Network Implementation Team (IT-5)

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ATSC Tower Network Implementation-Team (IT-5)

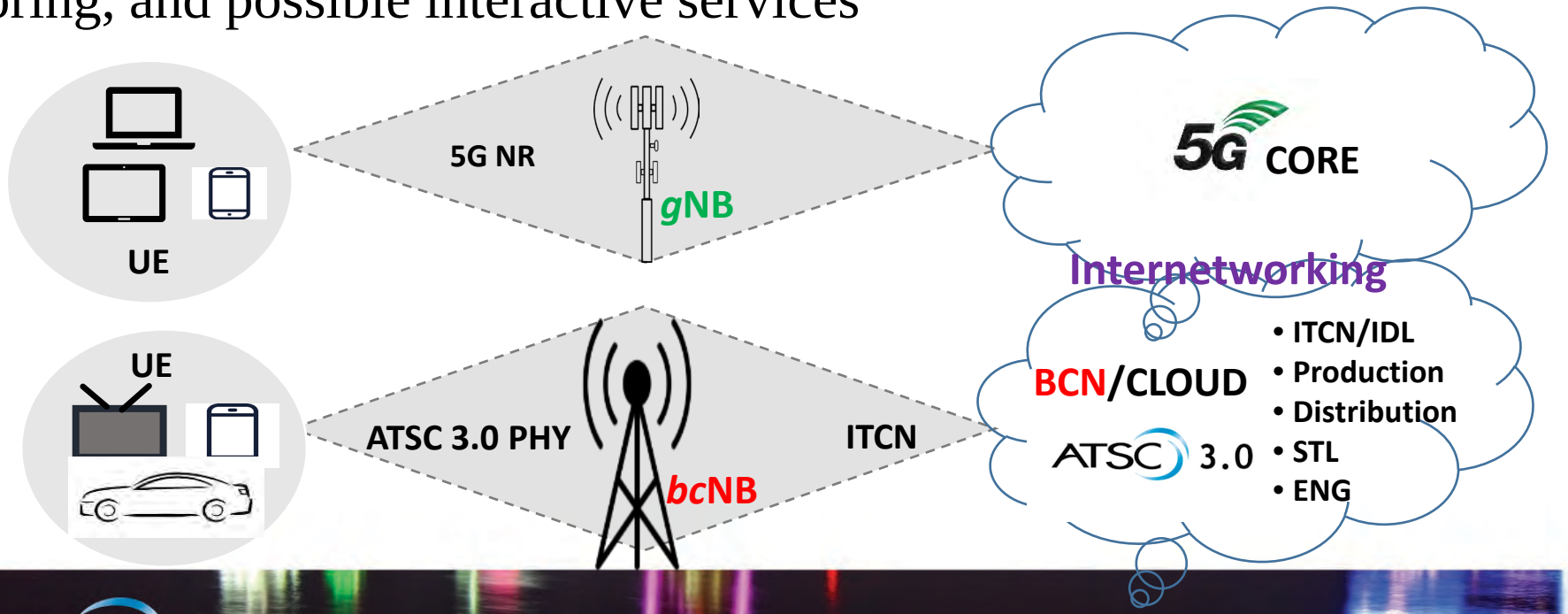
- IT-5 is one of the ATSC Implementation Teams on Tower Network
- IT-5 mandate is to design, implement, test, validate, and demonstrate the Inter-Tower Communications Network (ITCN)
- ITCN is designed to link all broadcast towers to form a scalable and reconfigurable IP-based network embedded within the terrestrial broadcast system and independent of any telecom infrastructure
- ITCN can internetwork with Broadcast Core-Network, telecom networks, Internet, and other systems.

5G Broadband Wireless vs. ATSC 3.0 NextGEN TV

5G System	ATSC 3.0
Point-to-Point Access Network	One-to-Many Broadcast Network
5G Core Network	Broadcast Core Network (under development by ATSC S43)
Tower-Based Data Network Fibre backbone/Integrated Access & Backhaul	Inter-Tower Communications Network Full-Duplex Communication (under development by ATSC IT-5)

A broadcast Node (*bc*NB) is required

- At a 5G base station, there is a *g*NB to connect with 5G Core and access 5G NR
- At an ITCN tower, similarly a broadcast-NB (*bc*NB) is required to connect the Broadcast Core Network (BCN) and access the ATSC 3.0 PHY, as well as provide local data upload/download, SFN timing control, network control and monitoring, and possible interactive services

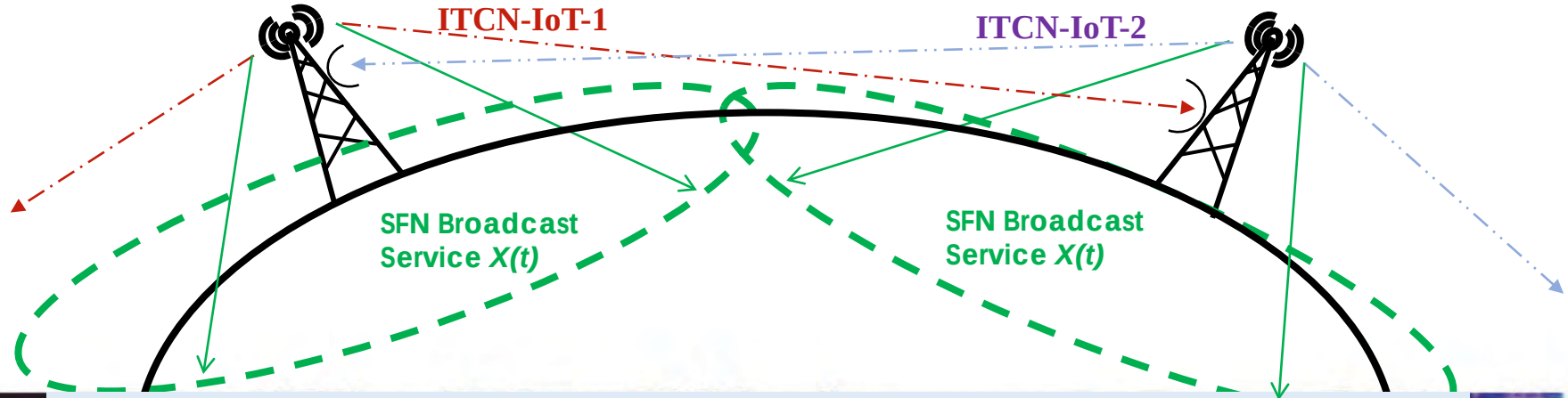


What is Inter-Tower Communications Network (ITCN)

- It connects broadcast towers to form an embedded IP network that re-uses broadcast spectrum and infrastructure
- It can provide localized services (content and advertisement), as well as IoT, connected cars, and other one-to-many datacasting services. It can also provide network control and monitoring
- It can provide wireless backhaul via In-band Distribution Link (IDL) to support Single Frequency Network (SFN) deployment to reduce capital and operating costs
- It is backward compatible with the ATSC 3.0 broadcast service

In-Band 2-Way Communications Between Towers

- TV service reception has a low receiving antenna height that has a small coverage area, due to terrain and structure blockage
- Broadcast tower can mount ITCN receiving antenna at a high location on the broadcast tower, reaching much further
- The most efficient but challenging case is the communication among SFN towers, where full-duplex communication needs to be implemented: transmitting and receiving on the same frequency. Signal cancellation techniques are implemented to receive the desired signal.

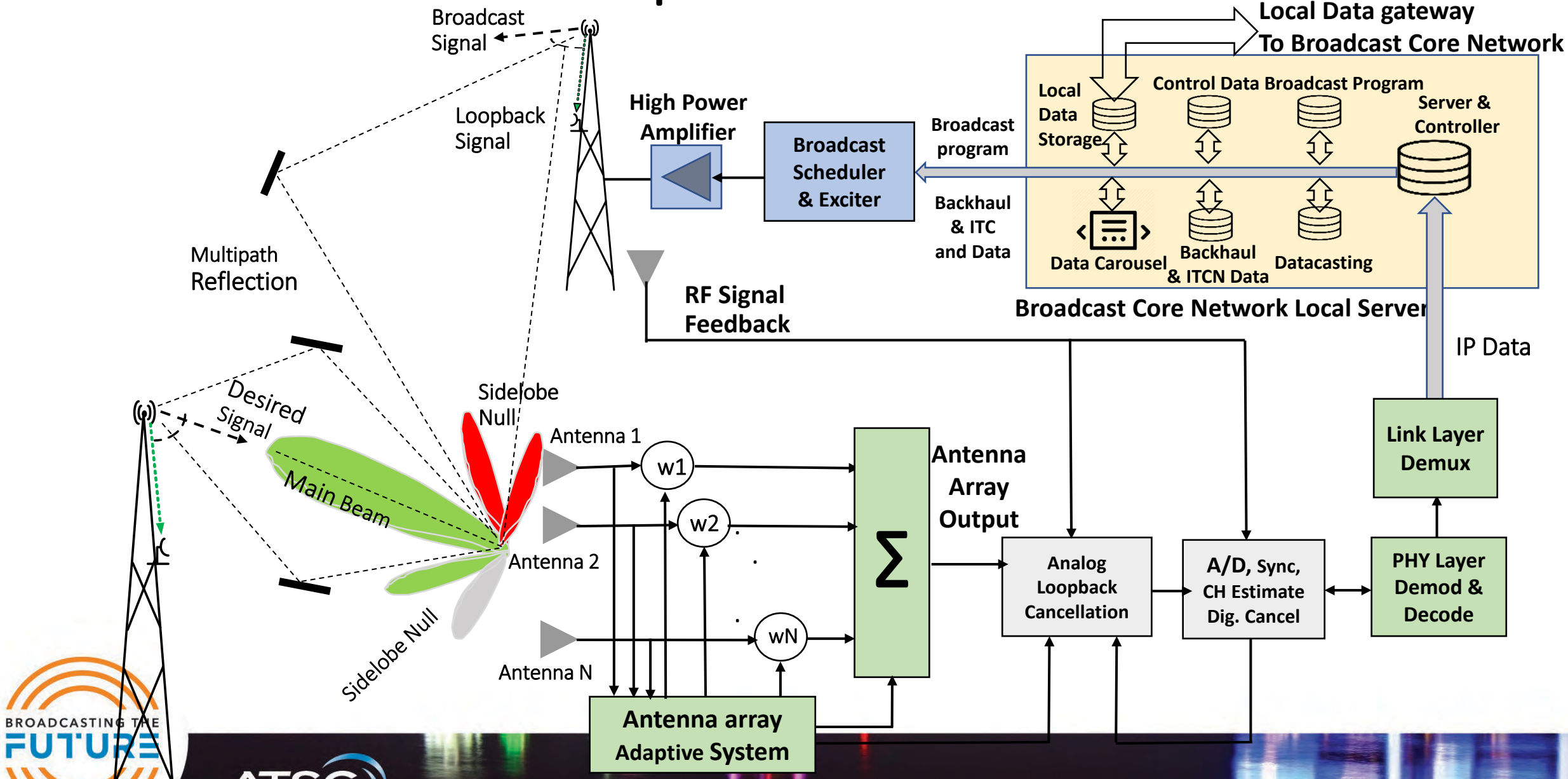


Three Different ITCN Broadcast and Data Services

1. Broadcast and datacast services to mobile/fixed terminals
2. Inter-Tower Communications: a 2-way, full-duplex wireless communications among broadcast towers, while enabling local datacasting in each tower's coverage area
3. SFN In-band Distribution Link (IDL): a 1-way, spectrum-efficient SFN signal distribution system using full-duplex

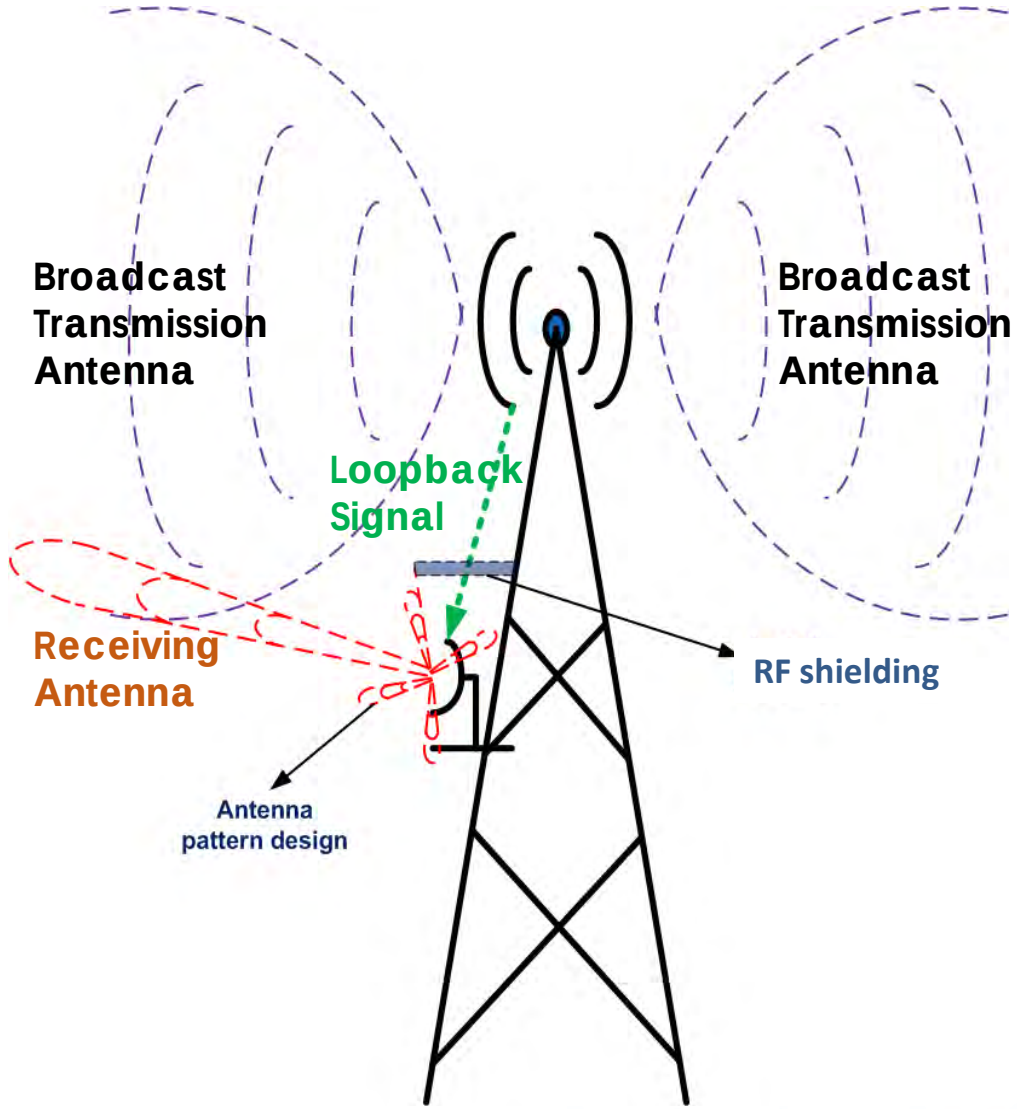
Note: ITCN can also operate under multi-frequency environments (out-of-band communications)

ITCN in In-Band Full-Duplex Mode



Two Implementations of ITCN

- Out-of-band communications
  - Transmitting and receiving signals in different RF channels
  - No loop-back self-interference (SI)
  - Require additional RF channel
- In-band full-duplex (IBFD)
  - Transmitting and receiving signals simultaneously in the same RF channel
  - High spectral efficiency
  - High self-interference (SI) from the local transmitter that can be 30 dB stronger than the remote desired signal



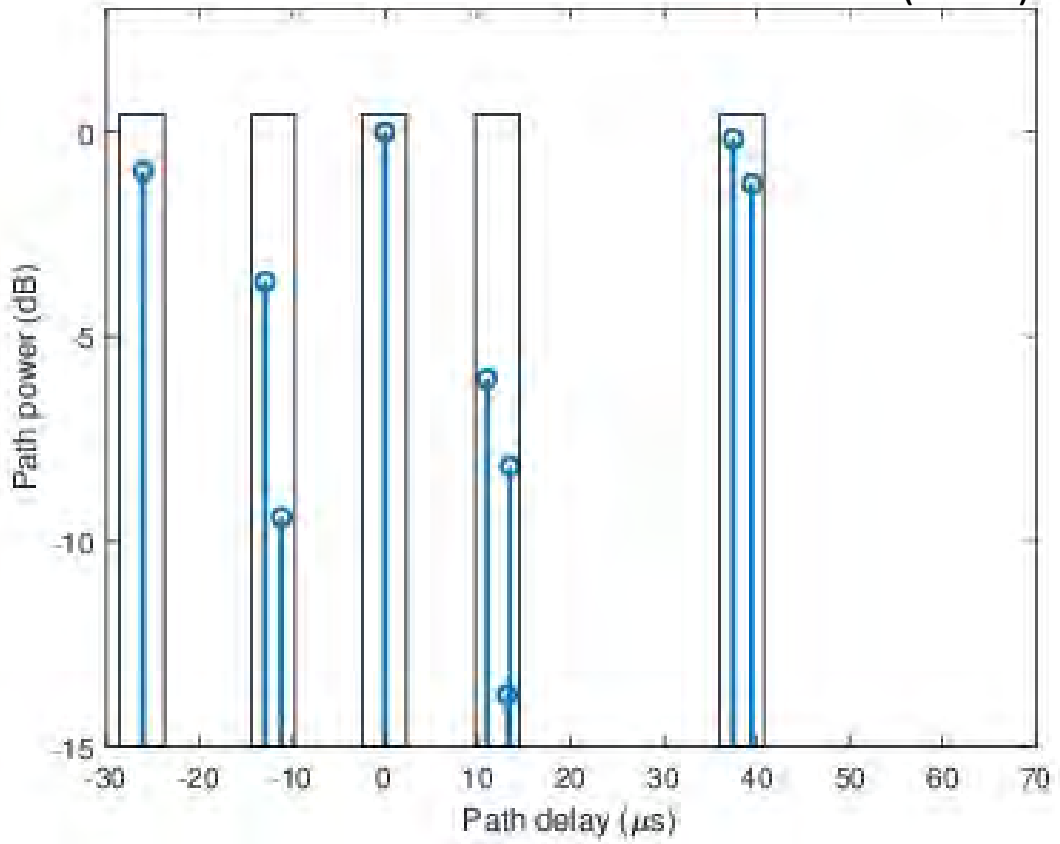
Challenges of ITCN with IBFD Communications

Unique challenges in broadcasting systems

- High transmission power and high transmitter nonlinear distortion
- Low frequency/low antenna directivity: large SFN signal multipath delay spread
- High order modulation: 1024QAM or 4096QAM for high ITCN data rate, which requires highly accurate self-interference cancellation to achieve high SNR (> 60 dB signal cancellation required)

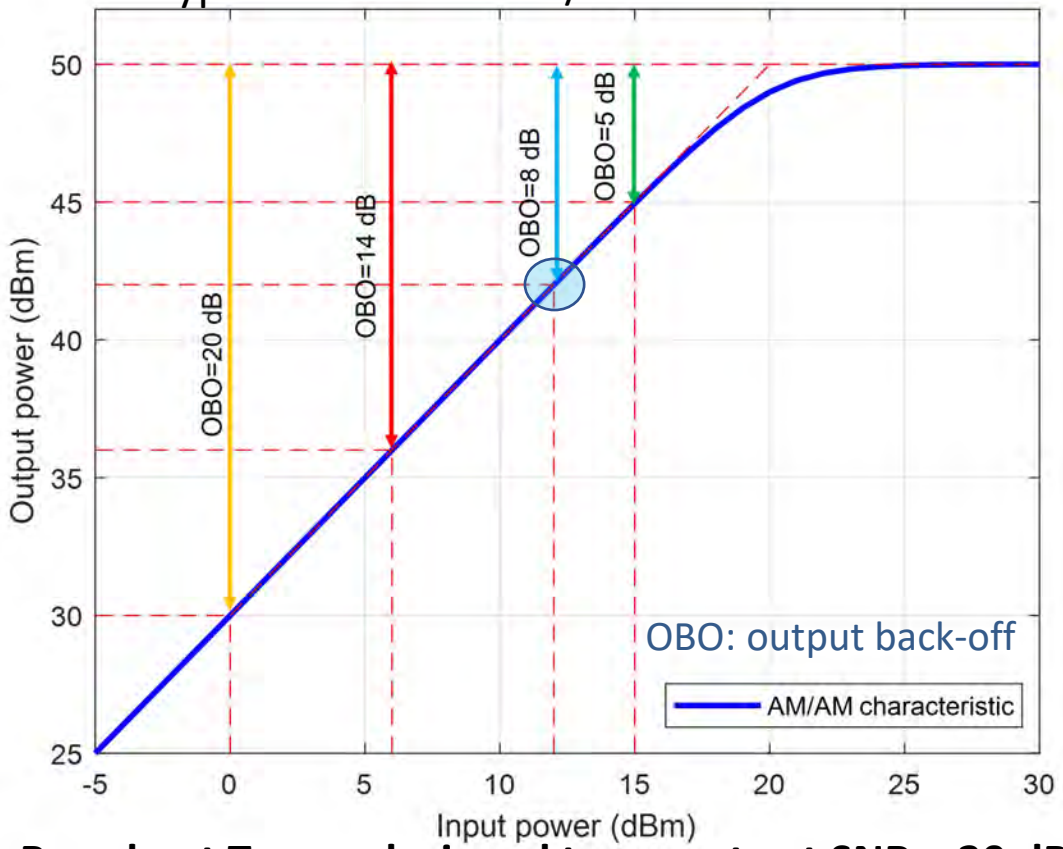
Large Delay Spread & Severe Power Amplifier Nonlinearity

ETRI measurement of SFN environment (6 TXs)



Seoul Area, 6 TXs SFN with 40 μS delay spread

Typical UHF SSPA AM/AM characteristic



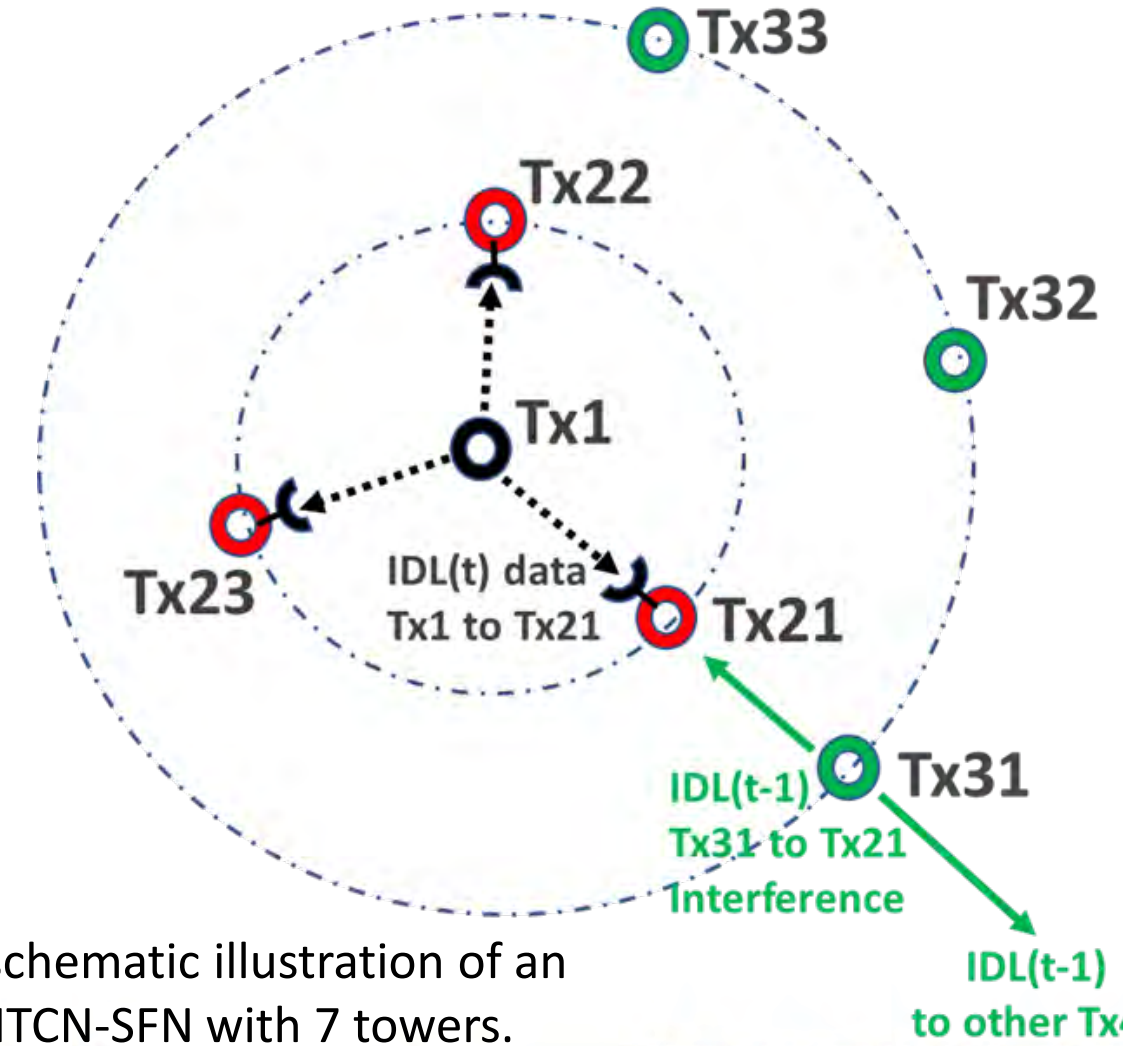
Broadcast Tx was designed to operate at SNR < 20 dB @ OBO = 8 dB for OFDM. Nonlinearity mitigation is required in order to achieve high SNR at the receiver without modification of the broadcast Tx operation.

S. Ahn et al., "Characterization and Modeling of UHF Wireless Channel in Terrestrial SFN Environments: Urban Fading Profiles," in IEEE Transactions on Broadcasting, 2022, doi: 10.1109/TBC.2022.3210382.

Challenges of ITCN with IBFD Communications in SFN

- Challenges in single frequency networks (SFN) environments
  - SFN creates an even larger delay spread
  - Co-channel interference
  - Remote channel estimation and signal acquisition

IDL: wireless in-band distribution link for spectrum-efficient backhaul.



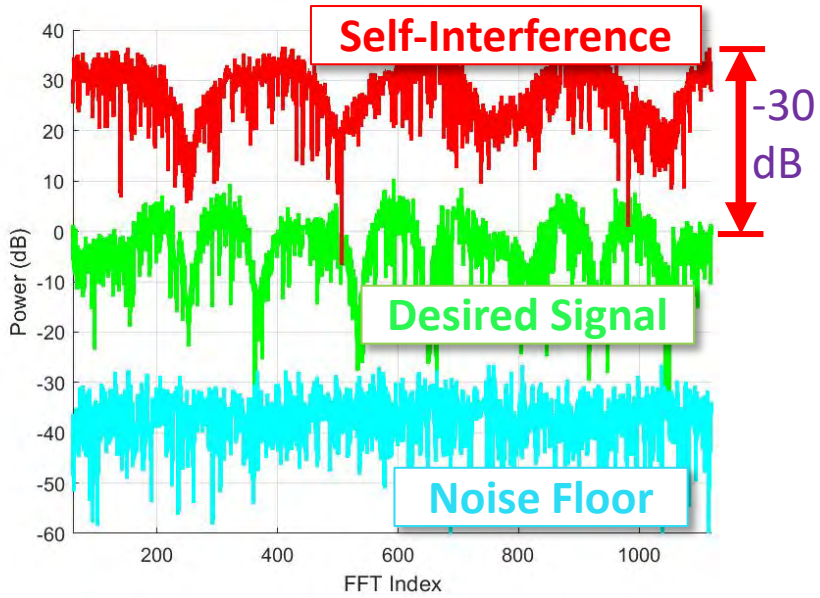
A schematic illustration of an ITCN-SFN with 7 towers.

CRC's R&D on IBFD Communications

- CRC developed self-interference cancellation (SIC) technology to meet the challenged requirements
  - Frequency domain cancellation (digital)
  - Capable of dealing with large multipath delay spread in SFN environment
  - Capable of mitigating high nonlinear distortion of broadcast transmitter power amplifier
  - No training phase/sequence is required for self-interference cancellation
  - Capable to suppress the self-interference to the receiver noise floor
  - Innovation on remote channel estimation with transmitter identification (TxID) sequence

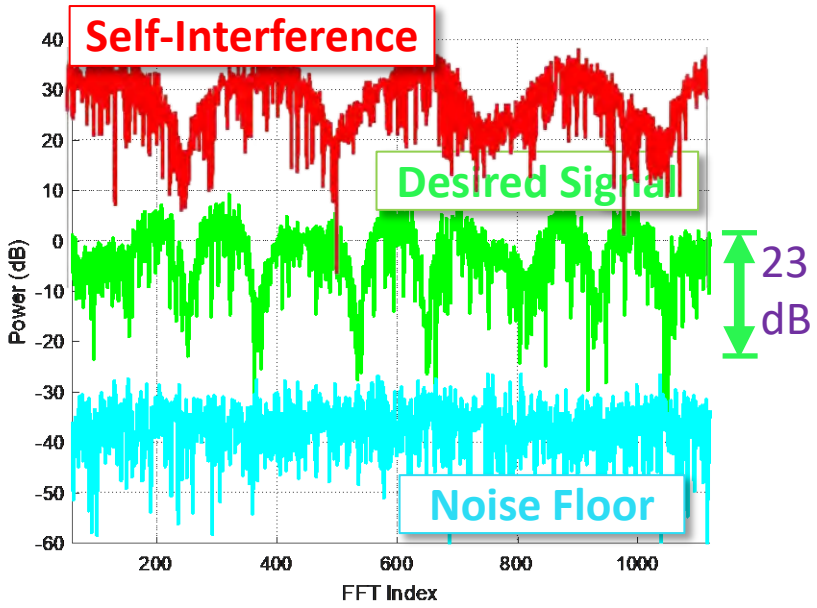
Frequency-Domain Iterative Self-Interference (SI) Cancellation for In-Band Full-Duplex Communications

Before SI cancellation



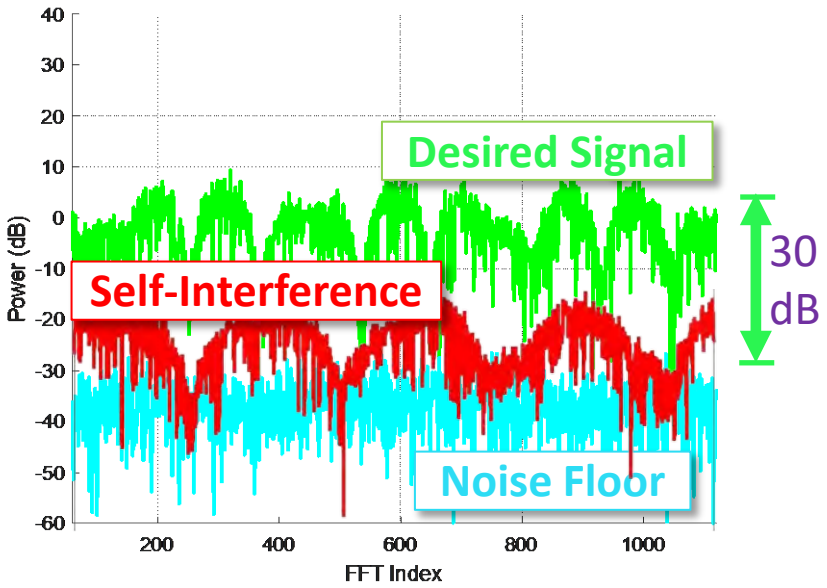
SNR = -30 dB, NO Reception

With 1-Stage Cancellation



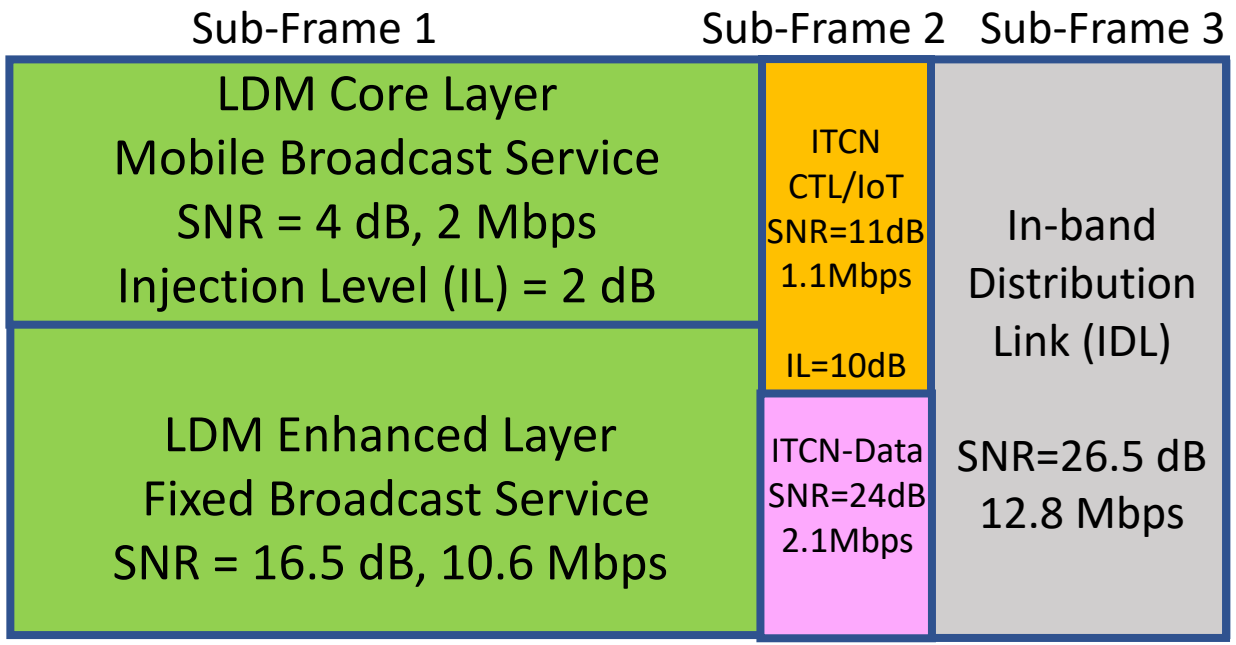
SNR = 23 dB

With 2-Stage Cancellation

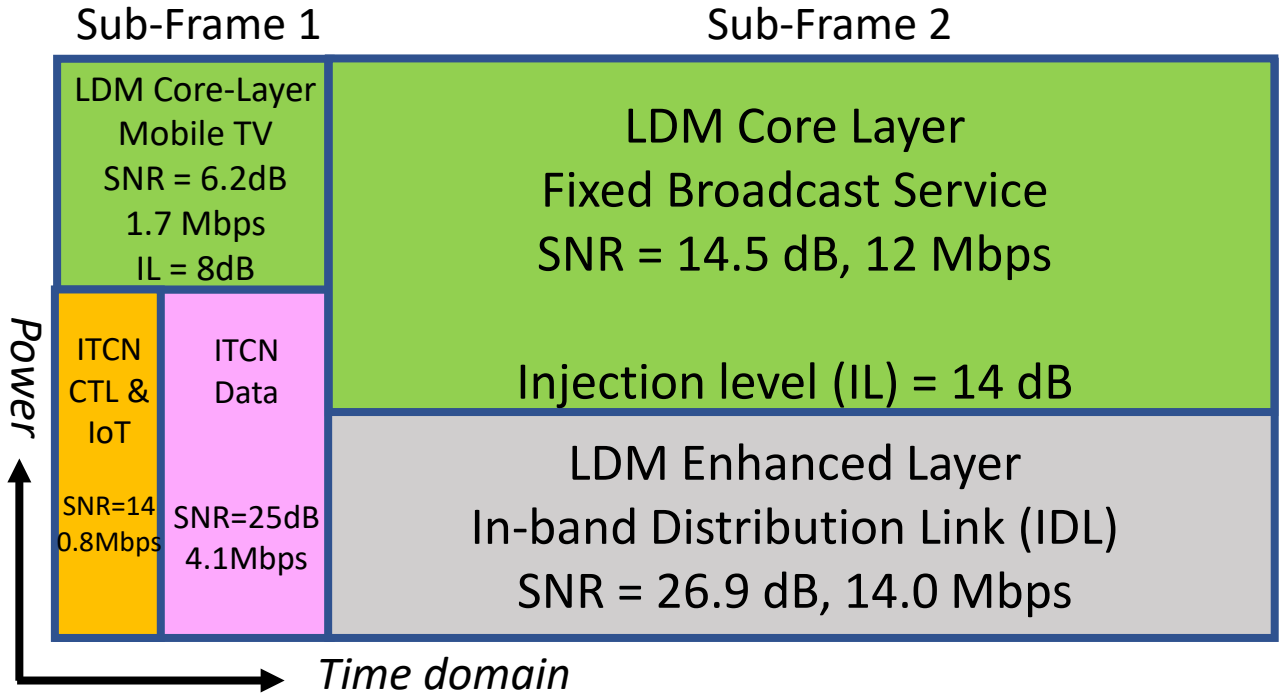


SNR = 30 dB

Broadcast/ITCN Overlay Network Signal Structure



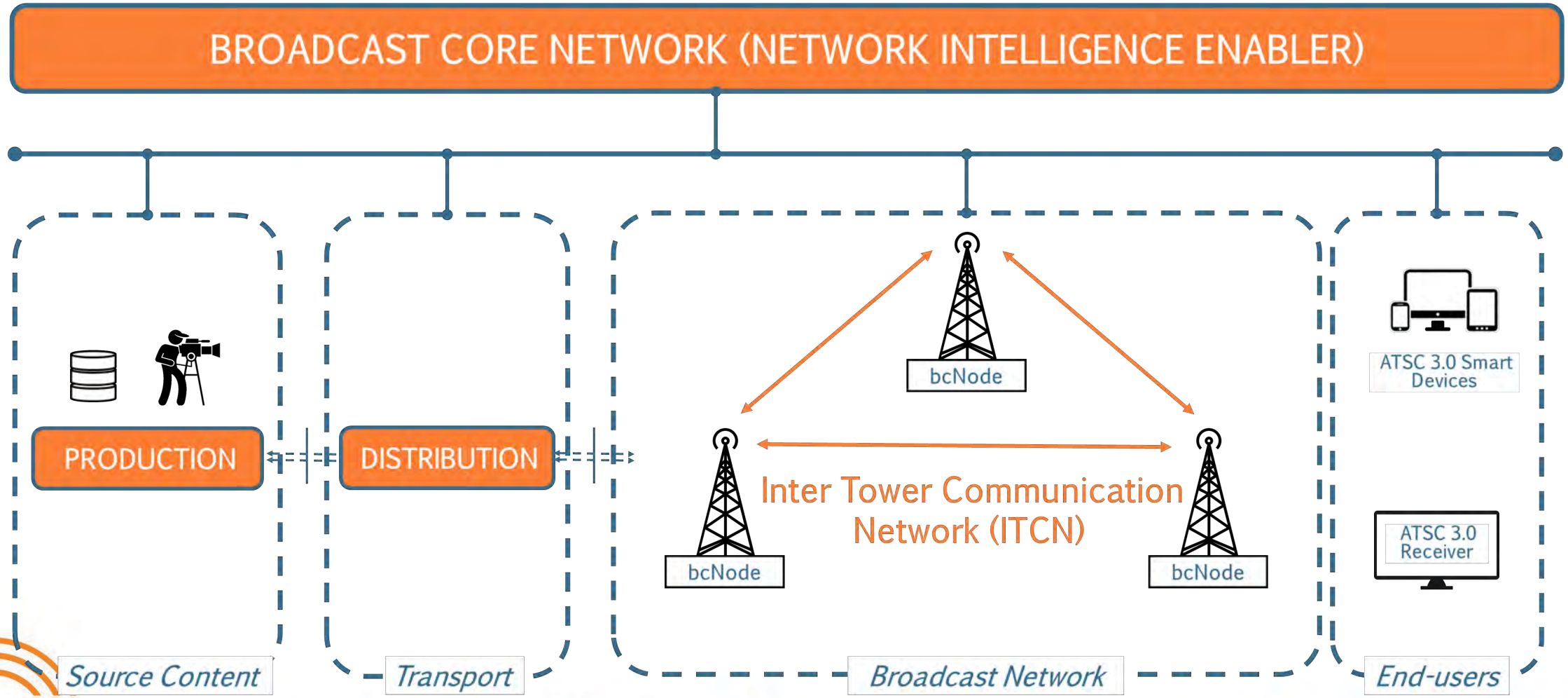
Broadcast and ITCN/IDL TDM Signal Structure
Aggregated data rate 28.7 Mbps



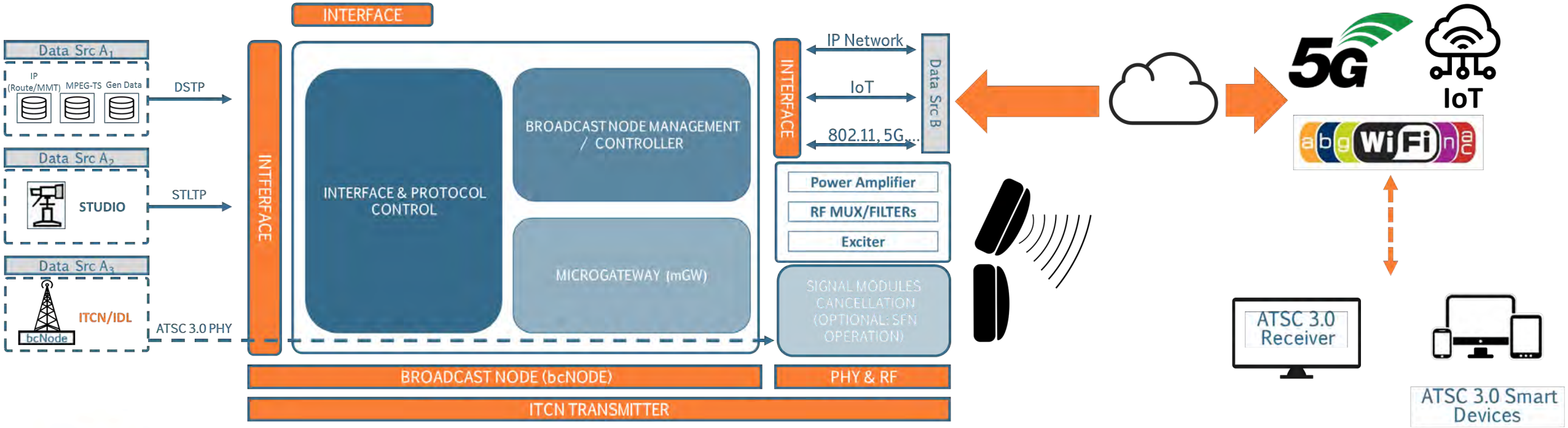
Broadcast and ITCN/IDL LDM Signal Structure
Aggregated data rate 32.7 Mbps

Layered Division Multiplexing (LDM) is used to integrate broadcast-datacast and ITCN/IDL services, while maintaining backward compatibility with ATSC 3.0 TV receivers

*bc*Node in ITCN, System Architecture

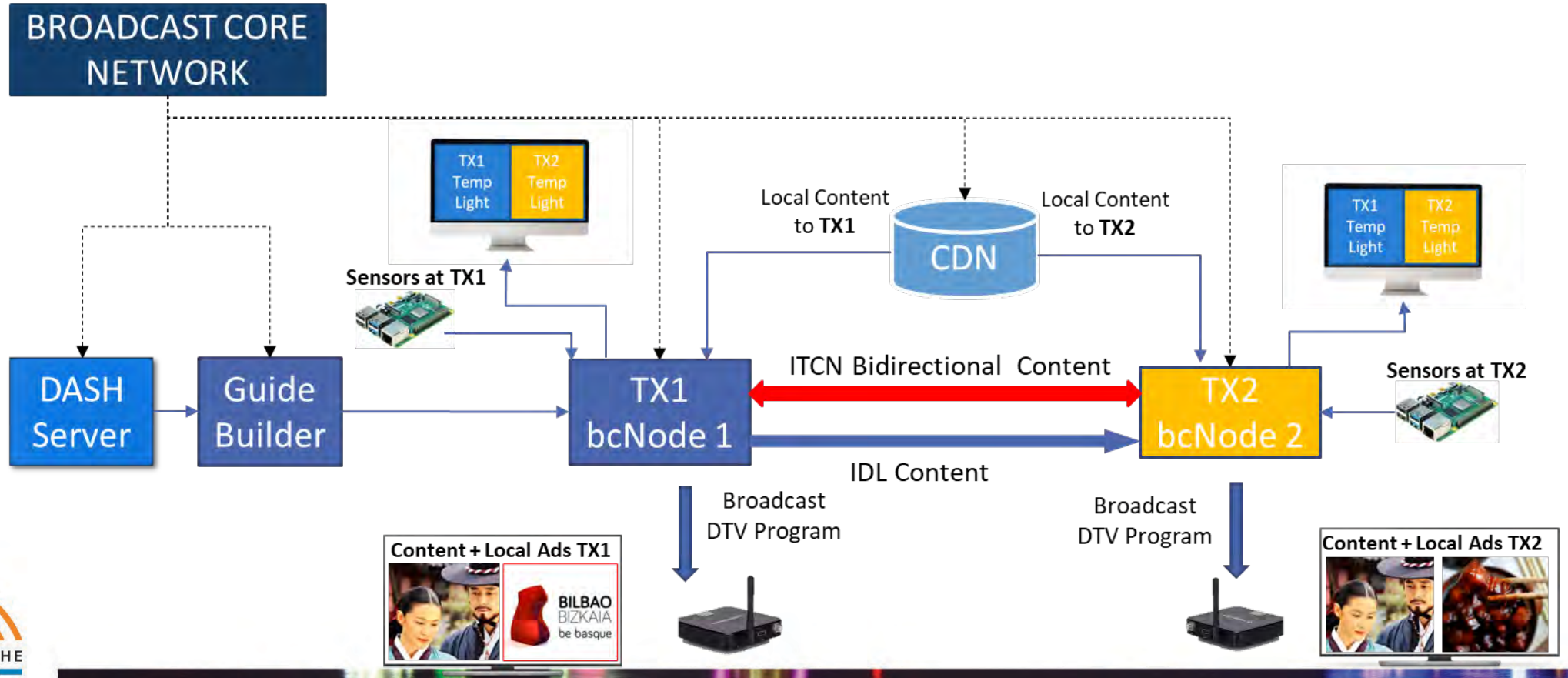


*bc*Node & ITCN, the Convergence Enabler



*bc*Nodes in ITCN, Demo System Diagram

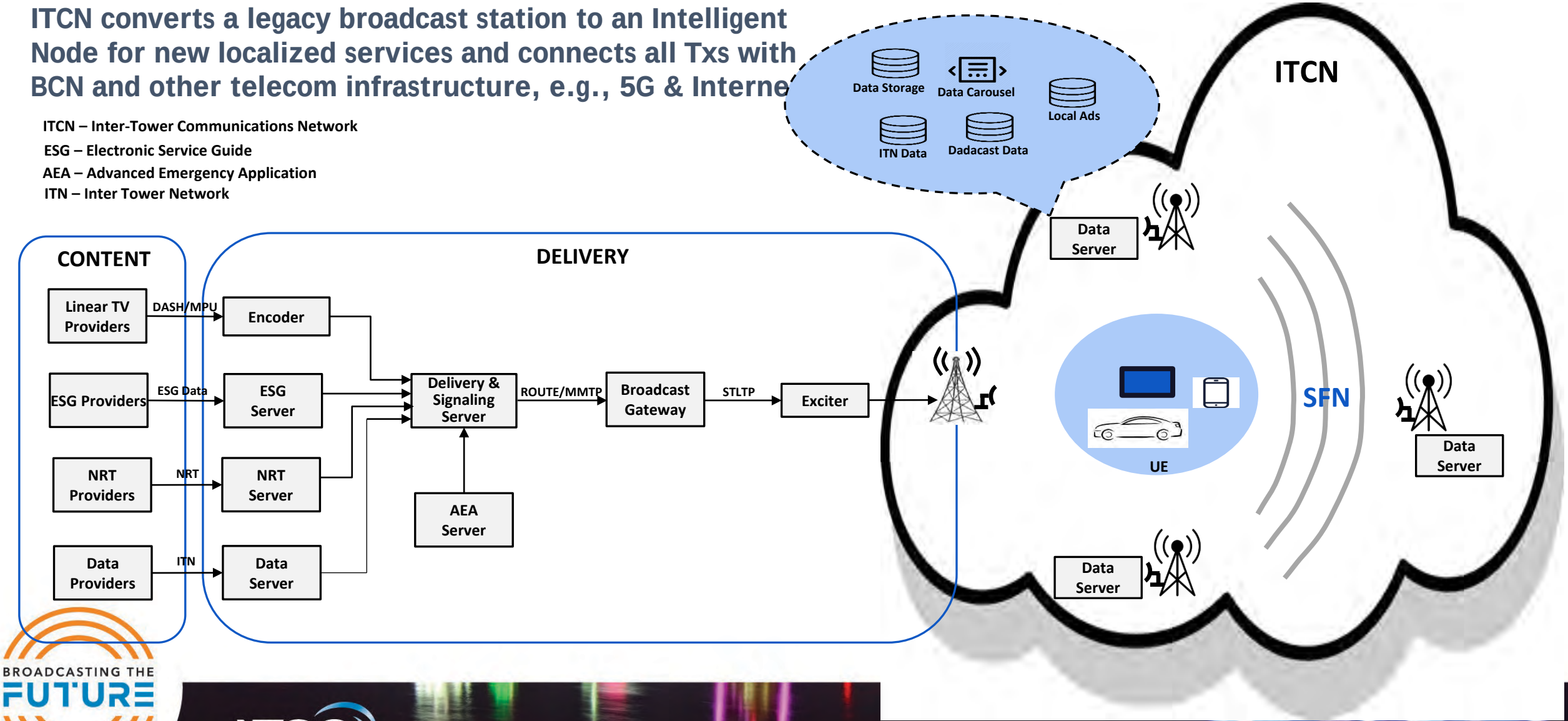
IDL + TWO WAY ITCN + LOCAL ADD CONTENT



The ITCN Big Picture

ITCN converts a legacy broadcast station to an Intelligent Node for new localized services and connects all Txs with BCN and other telecom infrastructure, e.g., 5G & Interne

ITCN – Inter-Tower Communications Network
ESG – Electronic Service Guide
AEA – Advanced Emergency Application
ITN – Inter Tower Network



Challenges and Innovations

- Develop a *Broadcast*-NodeB (*bc*NB)
- In the SFN environment, full-duplex communication needs to be implemented, where signal transmission and reception are on the same frequency band (spectrum re-use technology to improve spectrum efficiency)
- The interference signal cancellation range needs to be up to 1,000,000:1 (or 60 dB) for SFN In-band Distribution Link (IDL) operation
- To improve the spectrum efficiency, ITCN can use larger size FFT OFDM modulation and new error-correction codes for datacasting/IoT services. Three-layer LDM and MIMO technologies are also under investigation
- **ITCN/IDL is DTV standard agnostic. Any terrestrial DTV system can implement ITCN using LDM signal structure, while backward compatible with legacy TV receivers**

Inter-Tower Communications & Networks

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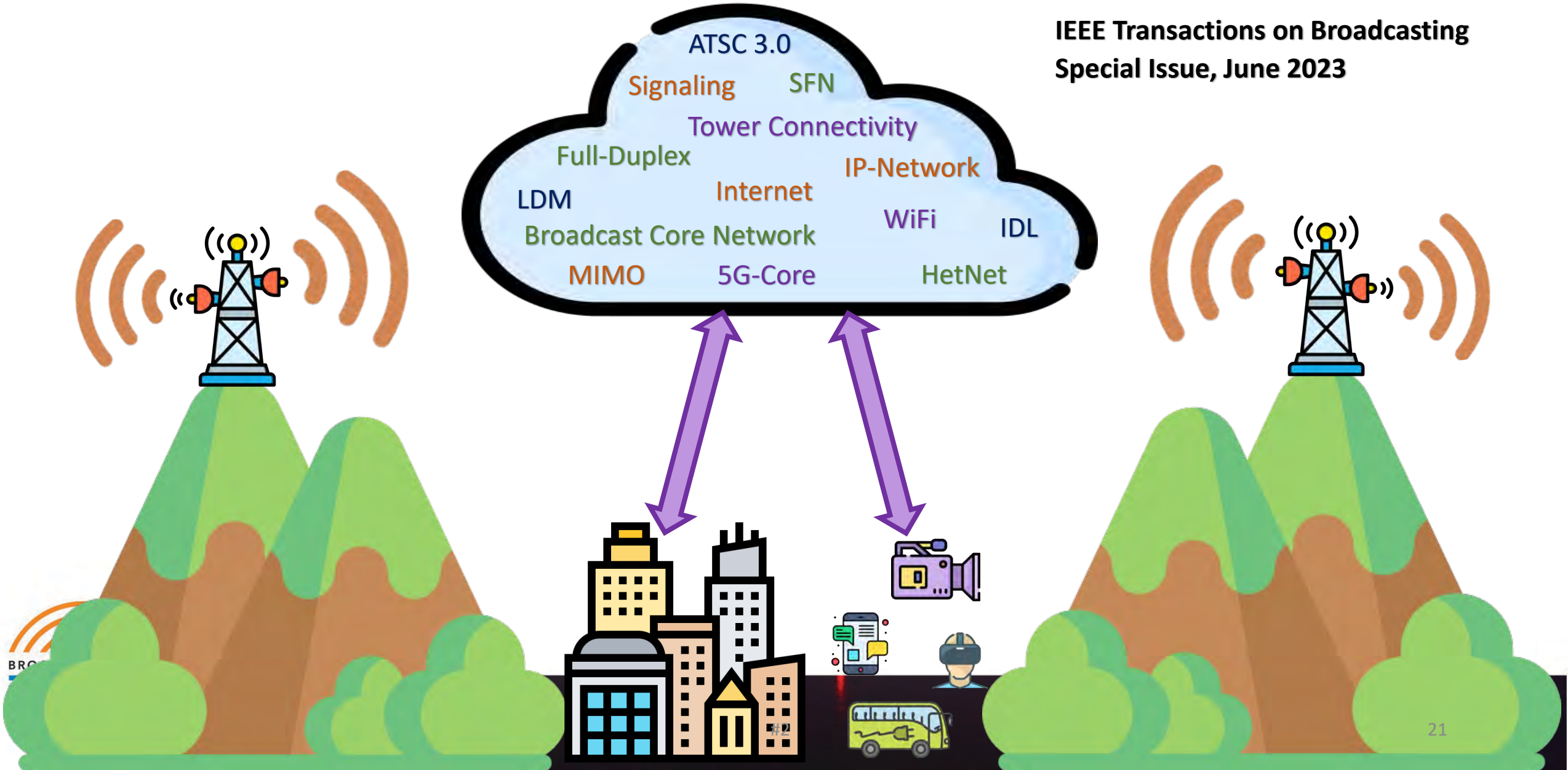
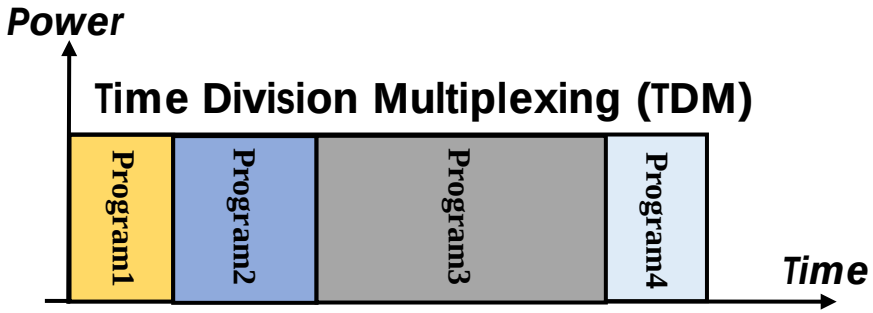
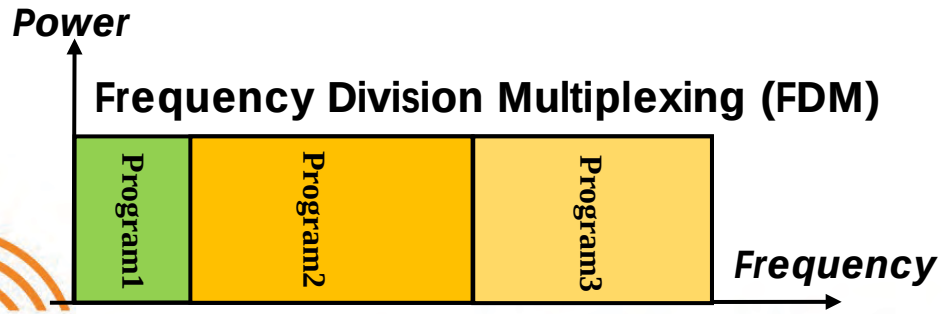


Thank You

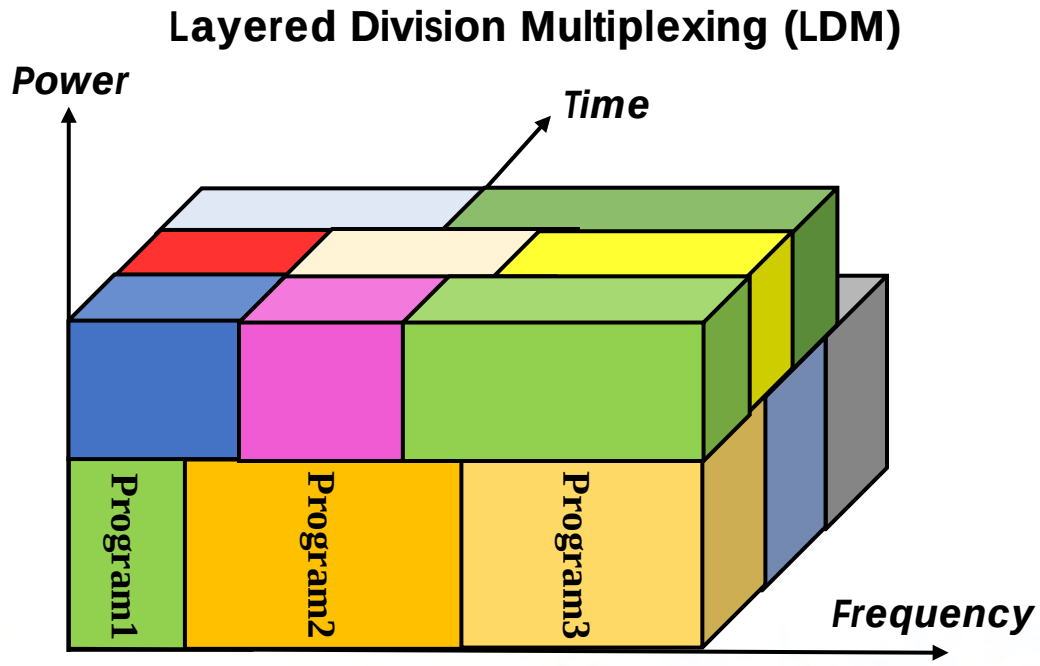
LDM: Transmitting

Can co-exist with traditional time & frequency division multiplexing





A spectrum re-use technology using power level and signal processing to "multiplex" (accommodate) more programs and services



LDM: Receiving

Signal processing technology used to separate layers