



Inter-Tower Communications Network (ITCN) for NextGEN TV

Humber Institute NextGEN TV Open House

ATSC Tower Network Implementation Team (IT-5)

Yiyan Wu C. M.
CRC Canada

Jon Montalban
U. Basque Country, Spain



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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

Point-to-Point Access Network

5G Core Network

Tower-Based Data Network

Fibre backbone/Integrated Access &
Backhaul

ATSC 3.0

One-to-Many Broadcast Network

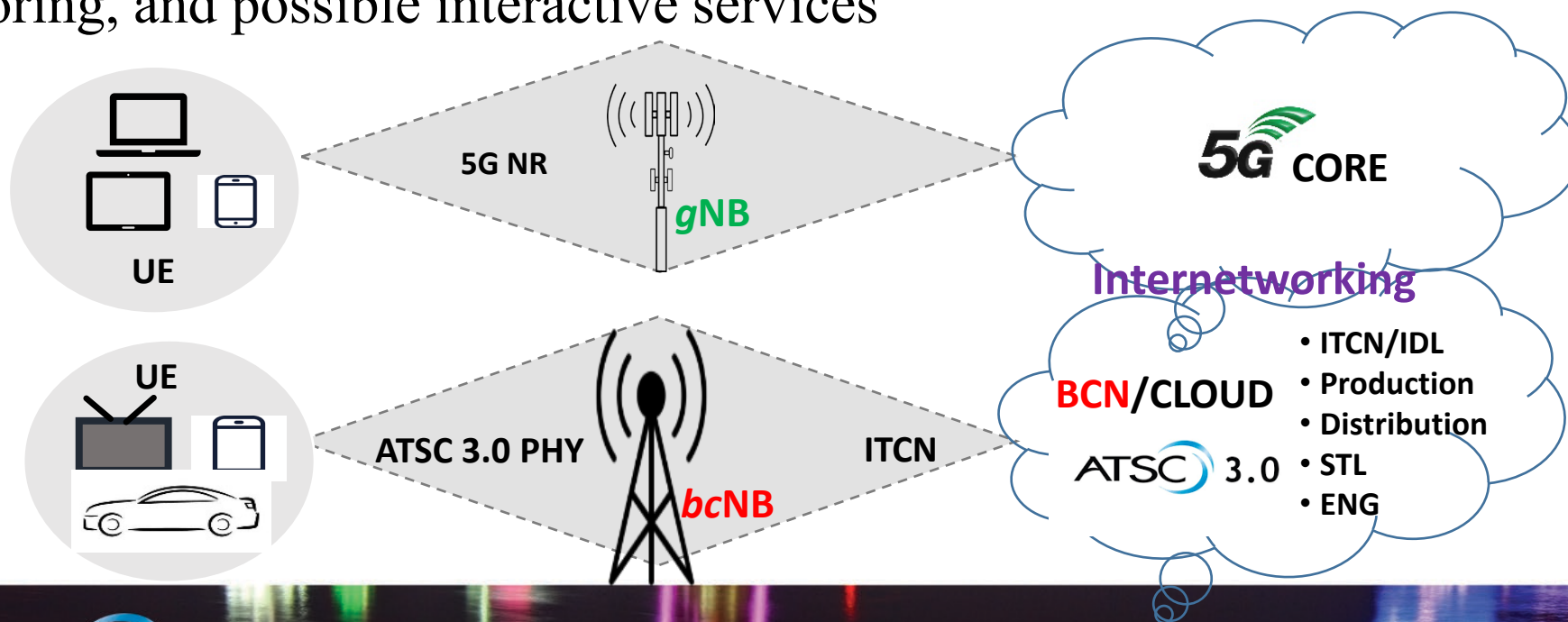
Broadcast Core Network
(under development by ATSC S43)

Inter-Tower Communications Network

Full-Duplex Communication
(under development by ATSC IT-5)

A broadcast Node (*bcNB*) is required

- At a 5G base station, there is a *gNB* to connect with 5G Core and access 5G NR
- At an ITCN tower, similarly a broadcast-NB (*bcNB*) 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

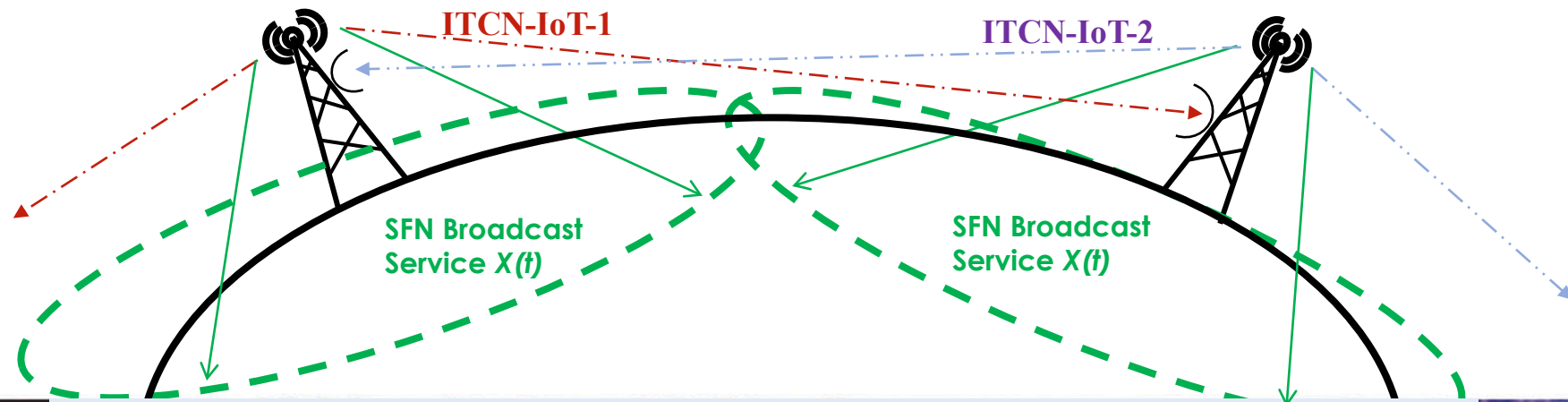


What is Inter-Tower Communications Network (ITCN) ⁵

- 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 ⁶

- 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.



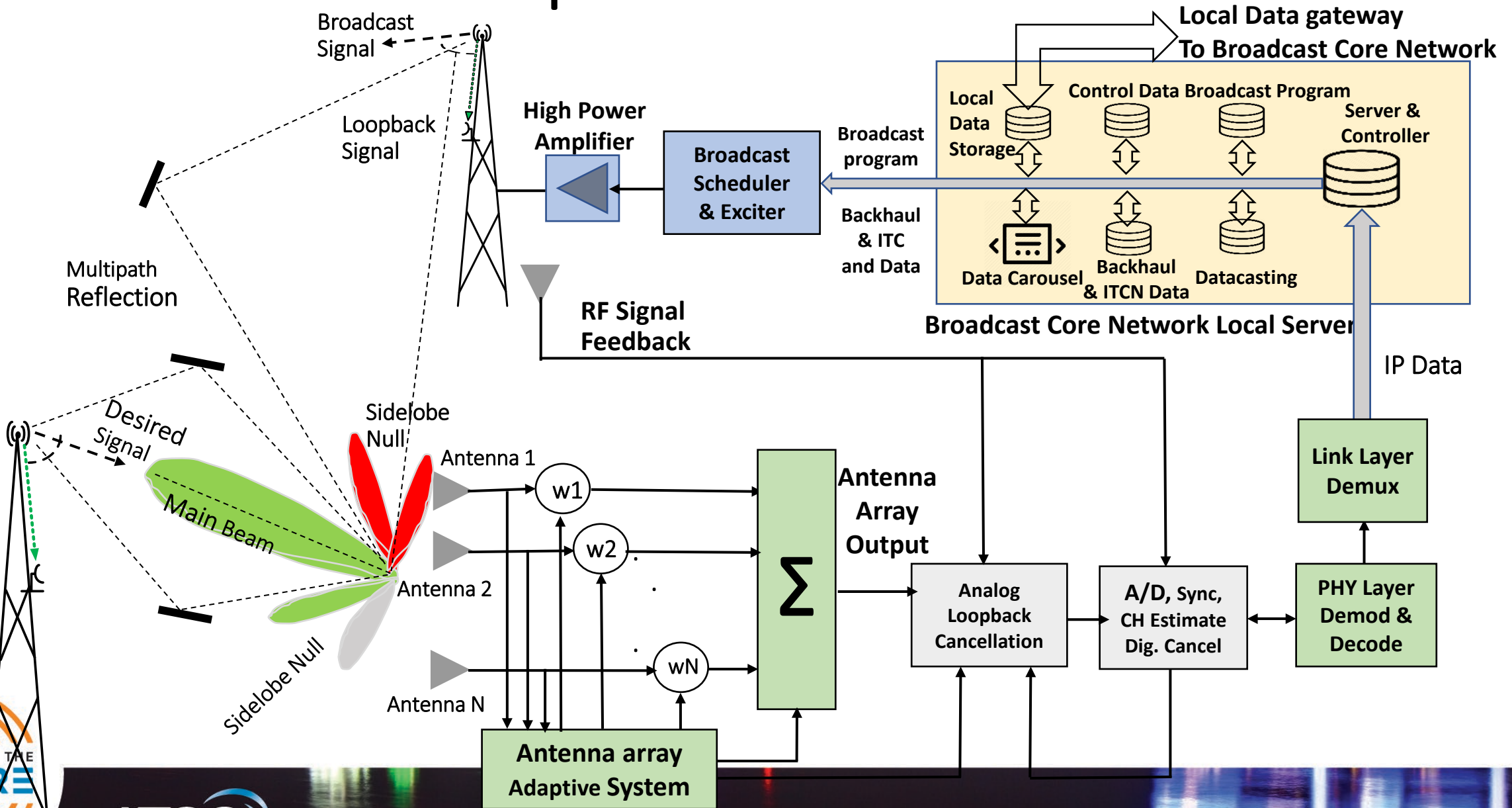
Three Different ITCN Broadcast and Data Services ⁷

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)

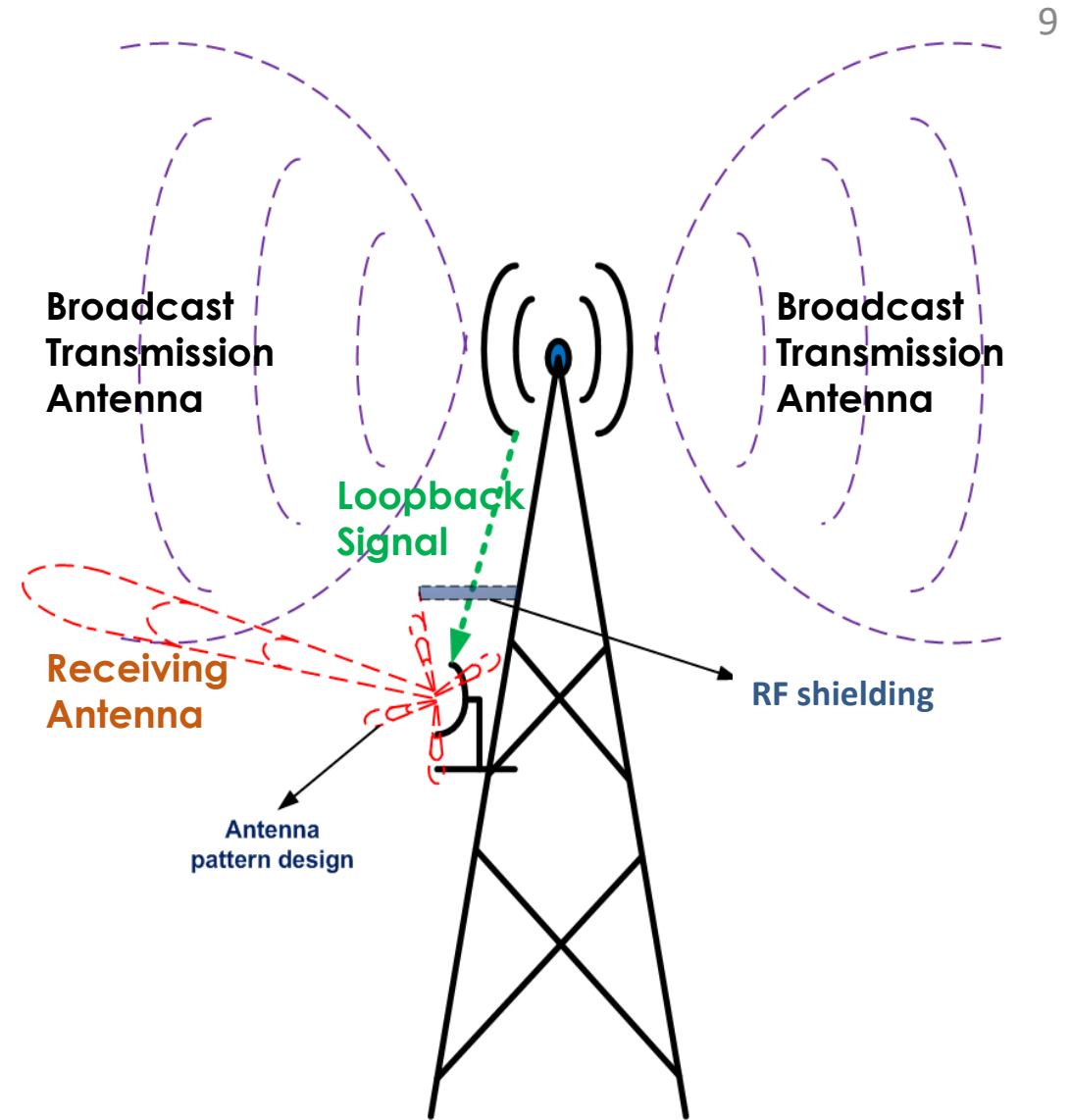


ITCN in In-Band Full-Duplex Mode



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

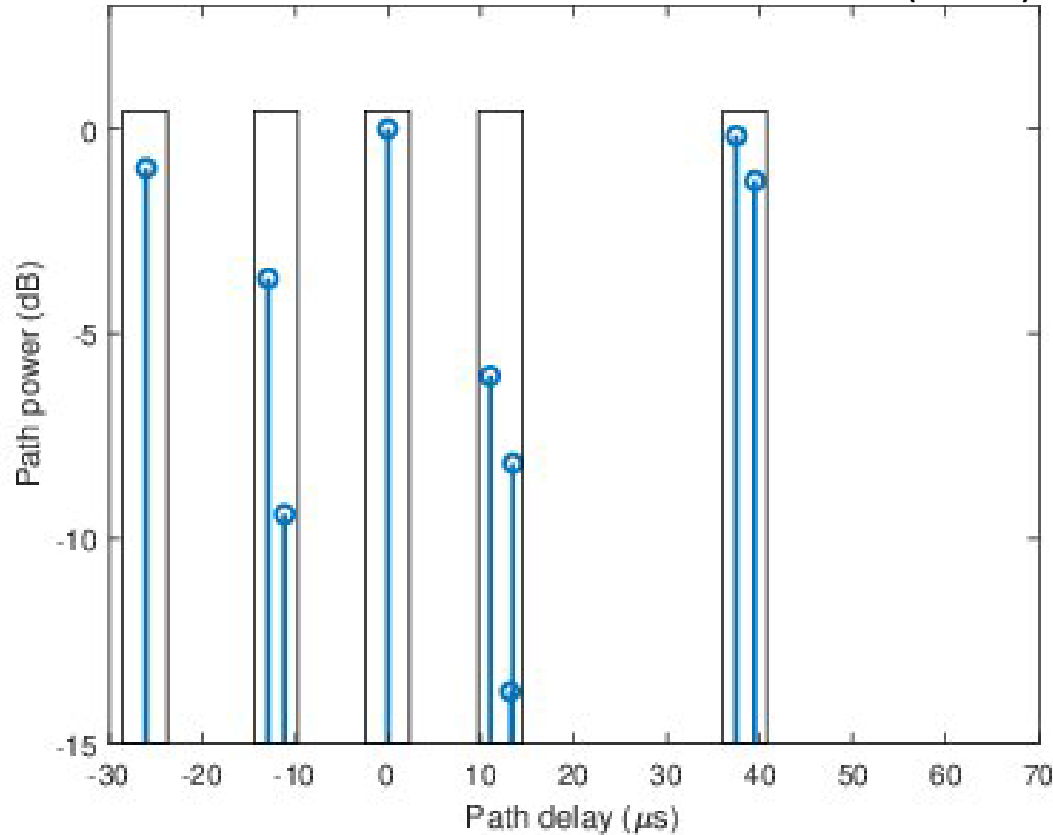
Unique challenges in broadcasting systems

- 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)



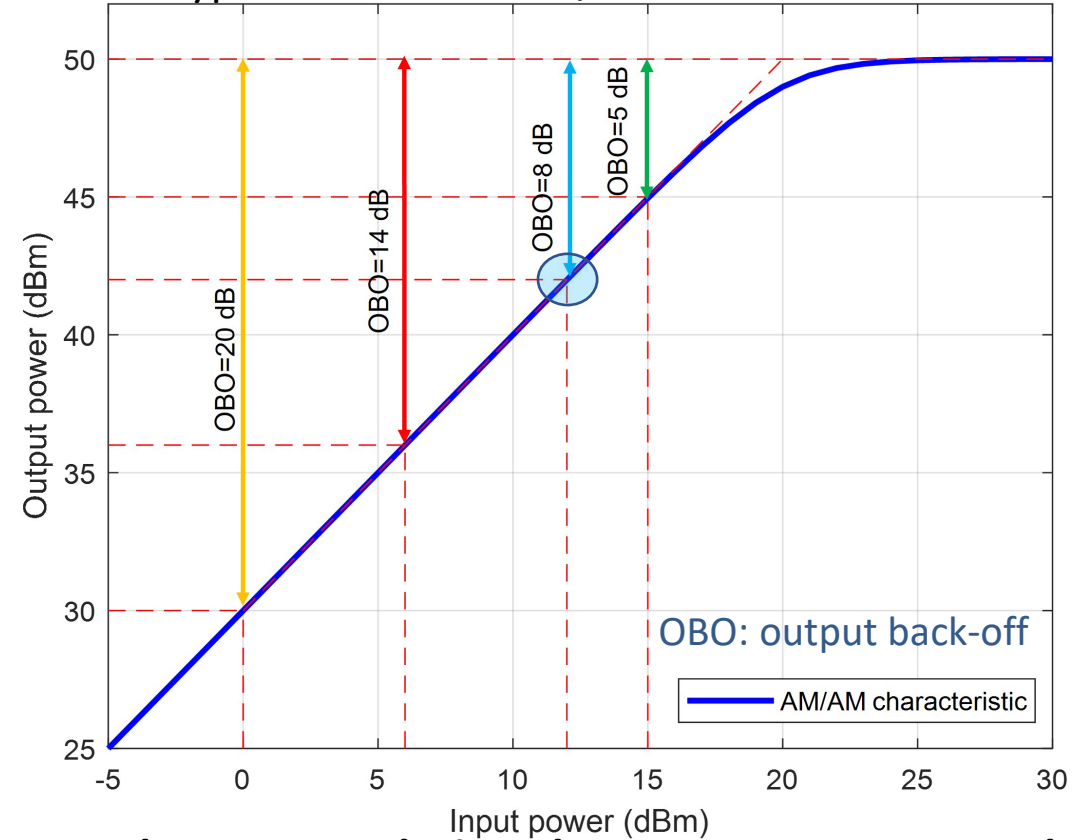
Large Delay Spread & Severe Power Amplifier Nonlinearity

ETRI measurement of SFN environment (6 TXs)



Seoul Area, 6 TXs SFN with 40 μs delay spread

Typical UHF SSPA AM/AM characteristic



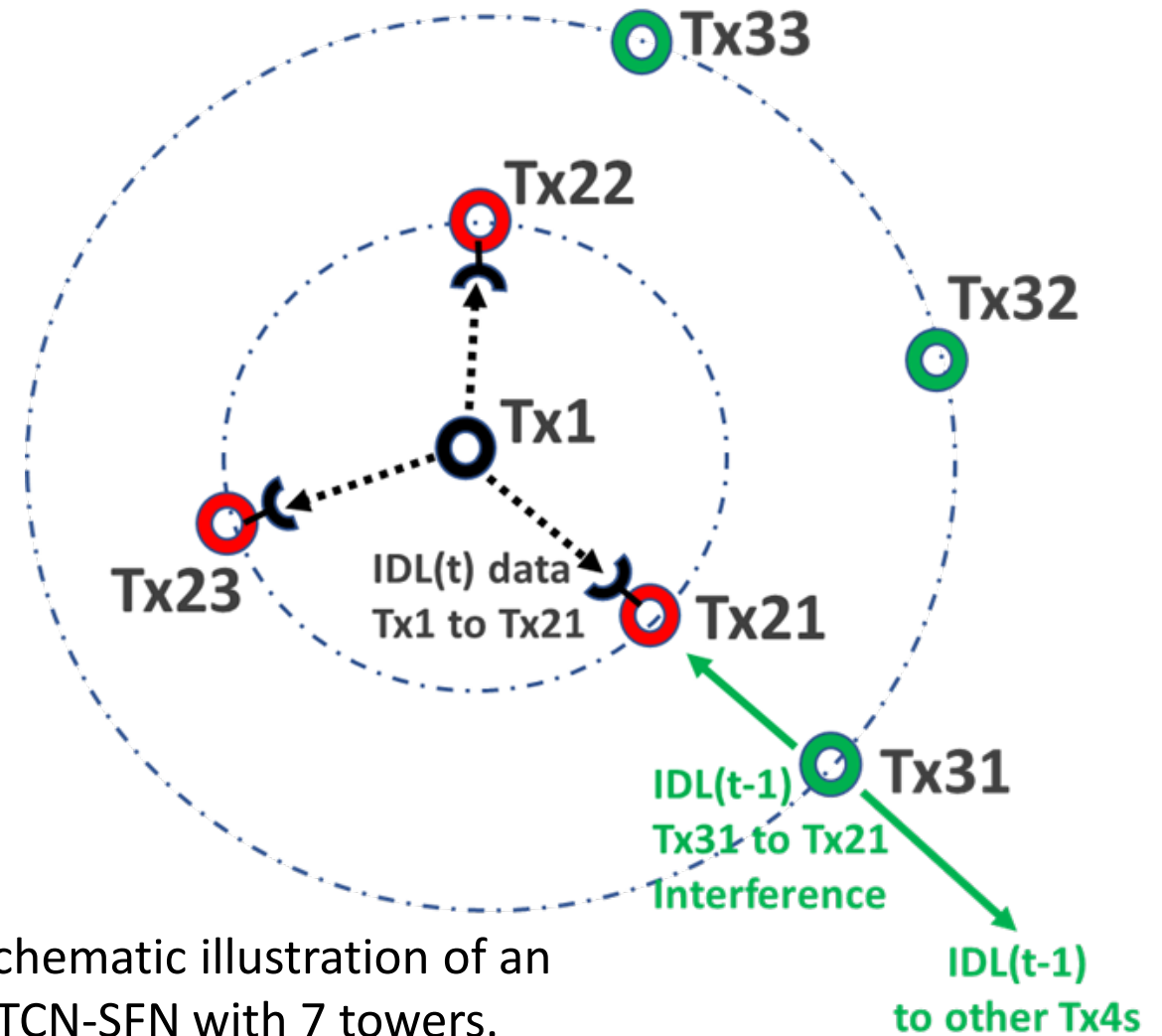
Broadcast Tx was designed to operate at SNR < 20 dB @ OBO = 8 dB for OFDM. Nonlinearity mitigation is required in order to achieve high SNR at the receiver without modification of the broadcast Tx operation.



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.



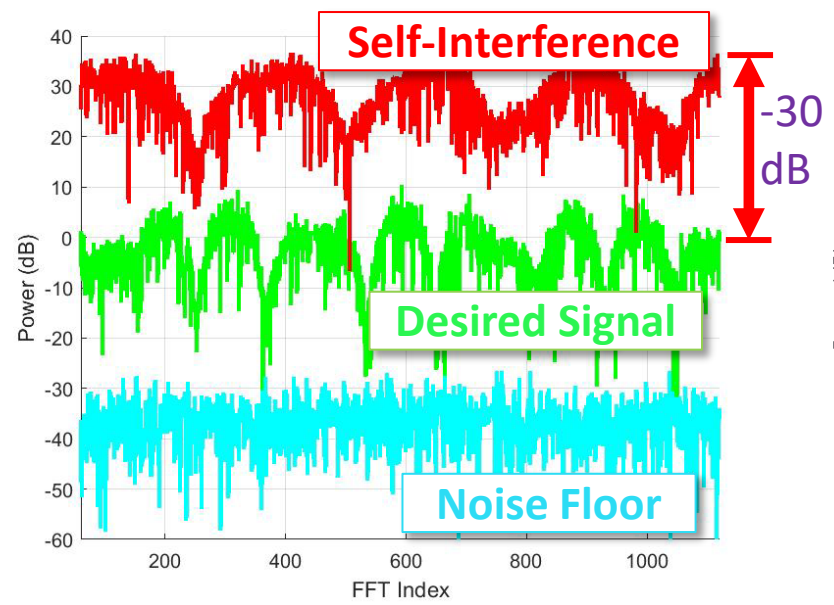
A schematic illustration of an ITCN-SFN with 7 towers.

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

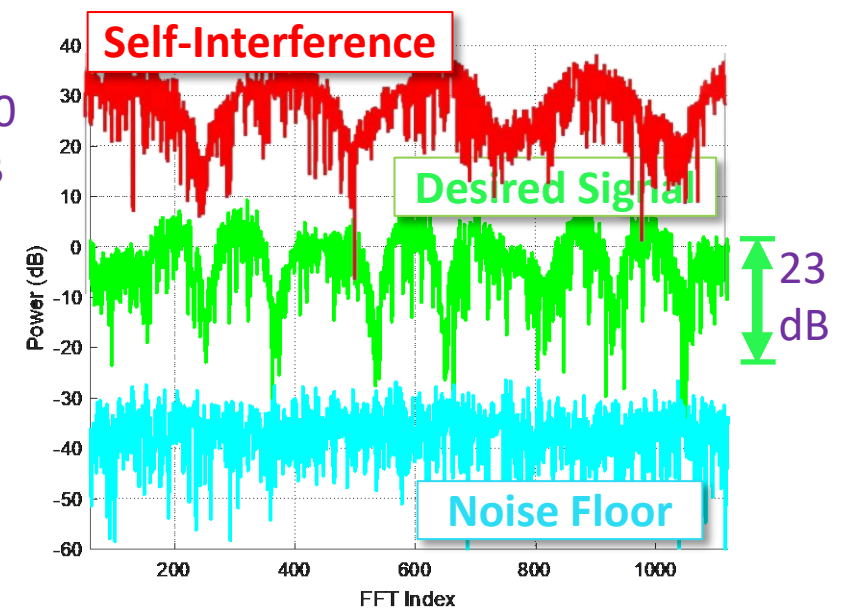
Frequency-Domain Iterative Self-Interference (SI) Cancellation for In-Band Full-Duplex Communications

Before SI cancellation



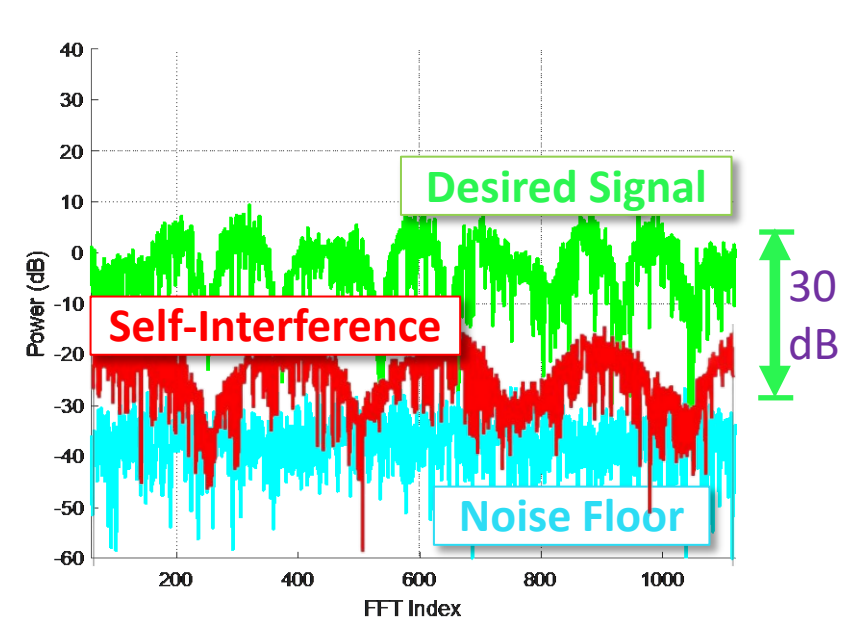
SNR = -30 dB, NO Reception ❌

With 1-Stage Cancellation



SNR = 23 dB ✓

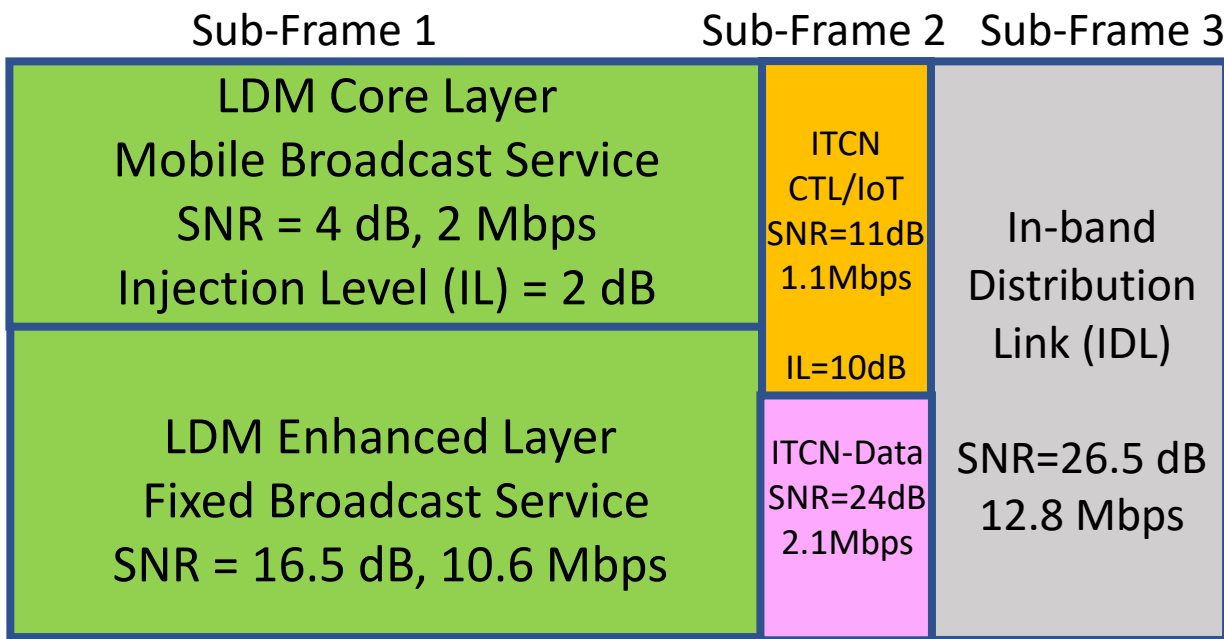
With 2-Stage Cancellation



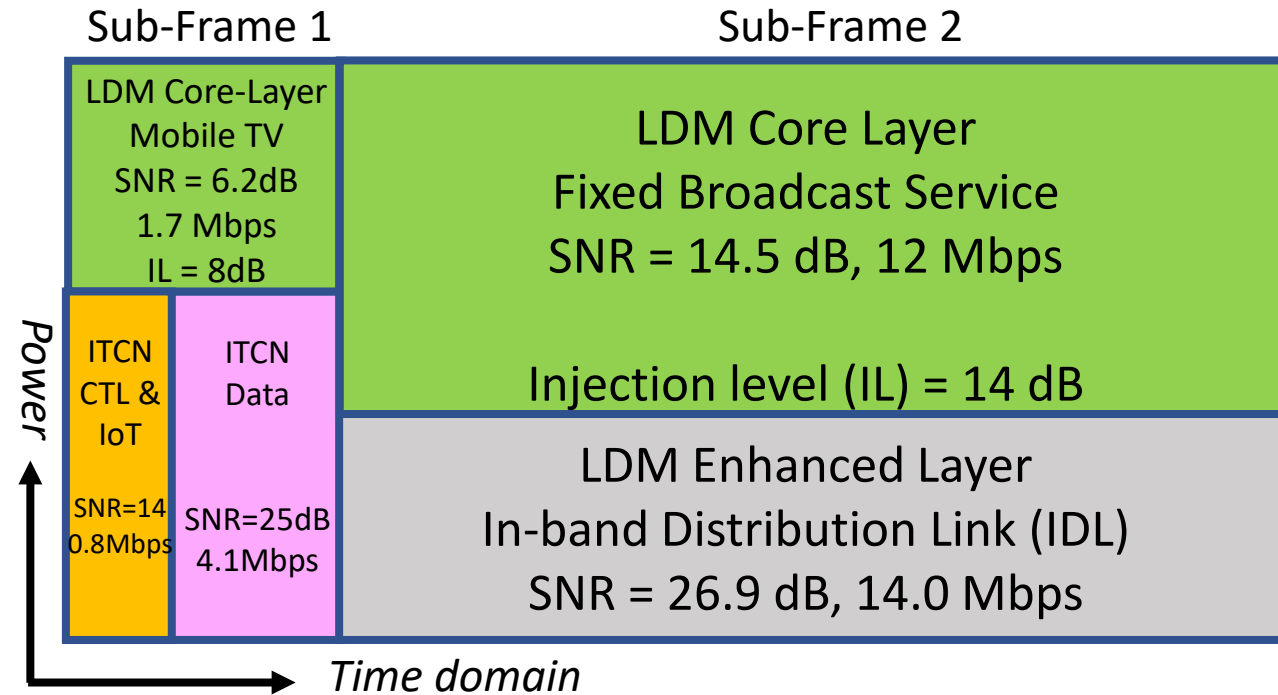
SNR = 30 dB ✓✓



Broadcast/ITCN Overlay Network Signal Structure ¹⁵



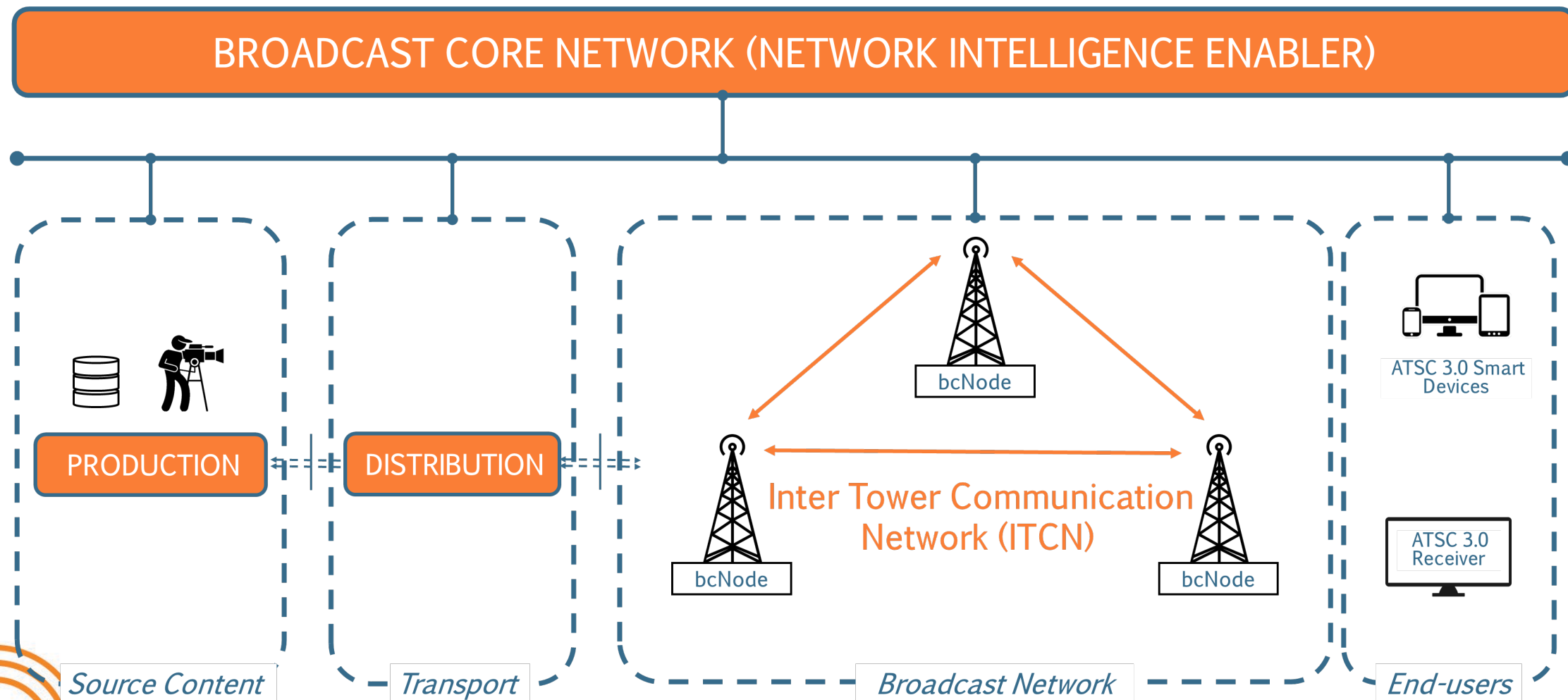
Broadcast and ITCN/IDL TDM Signal Structure
Aggregated data rate 28.7 Mbps



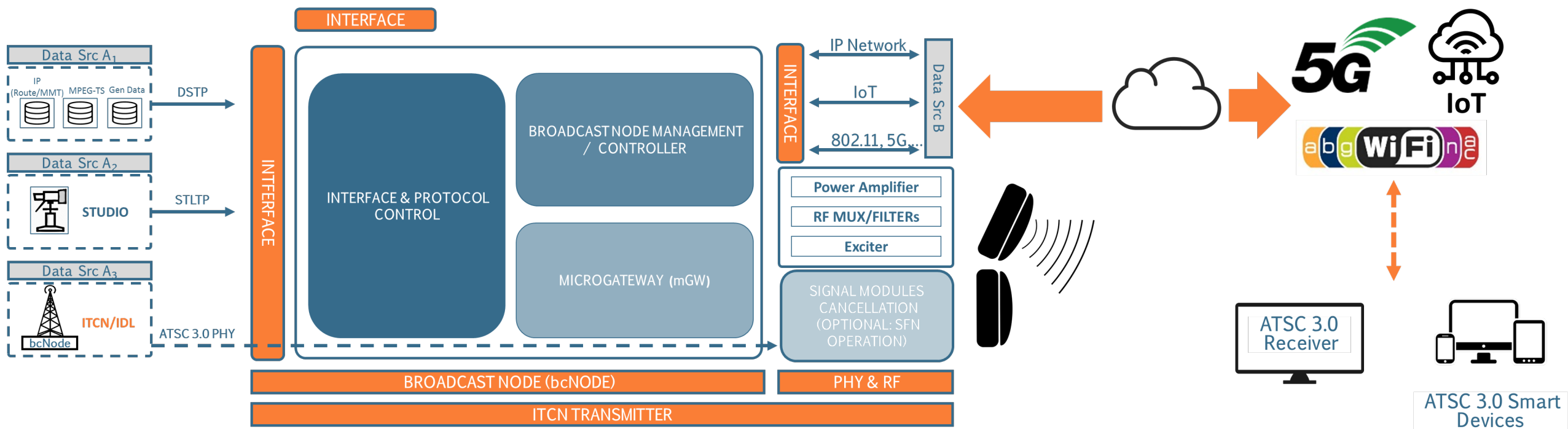
Broadcast and ITCN/IDL LDM Signal Structure
Aggregated data rate 32.7 Mbps

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

bcNode in ITCN, System Architecture

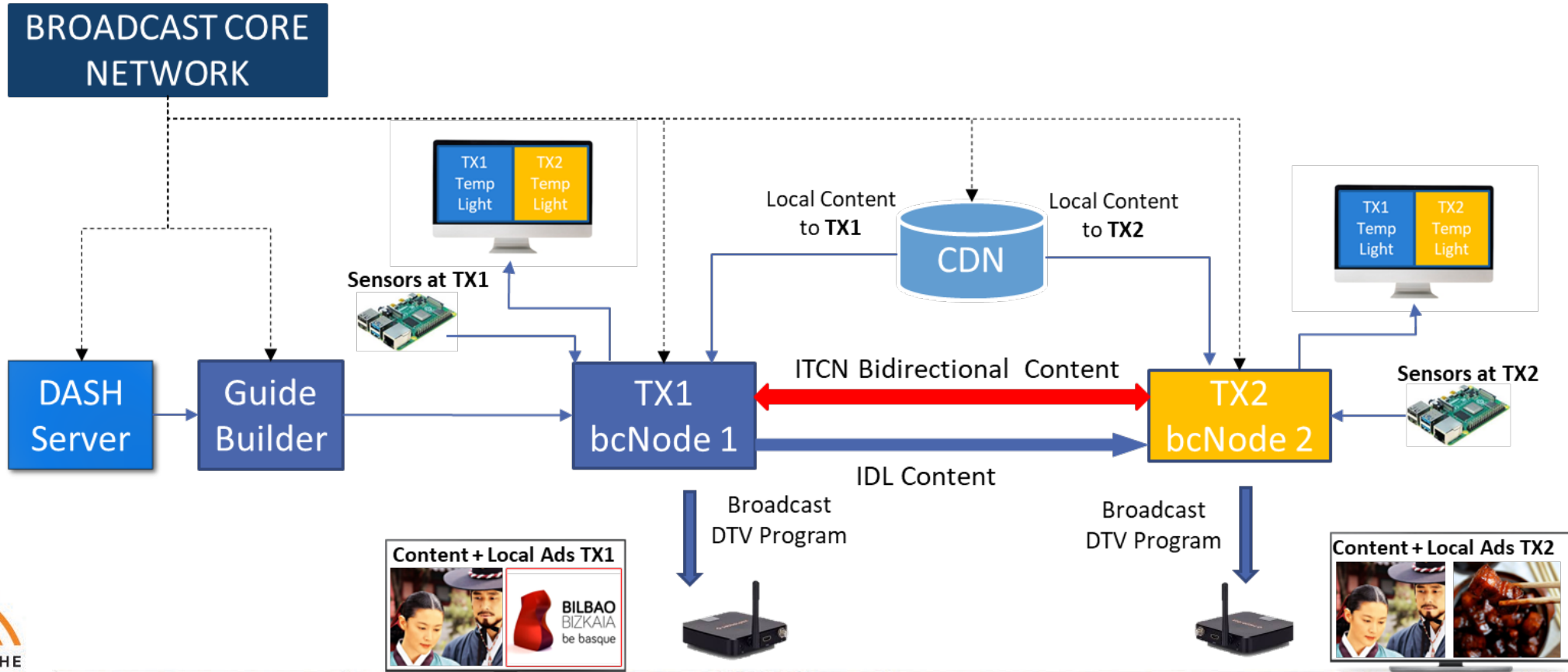


bcNode & ITCN, the Convergence Enabler



bcNodes in ITCN, Demo System Diagram

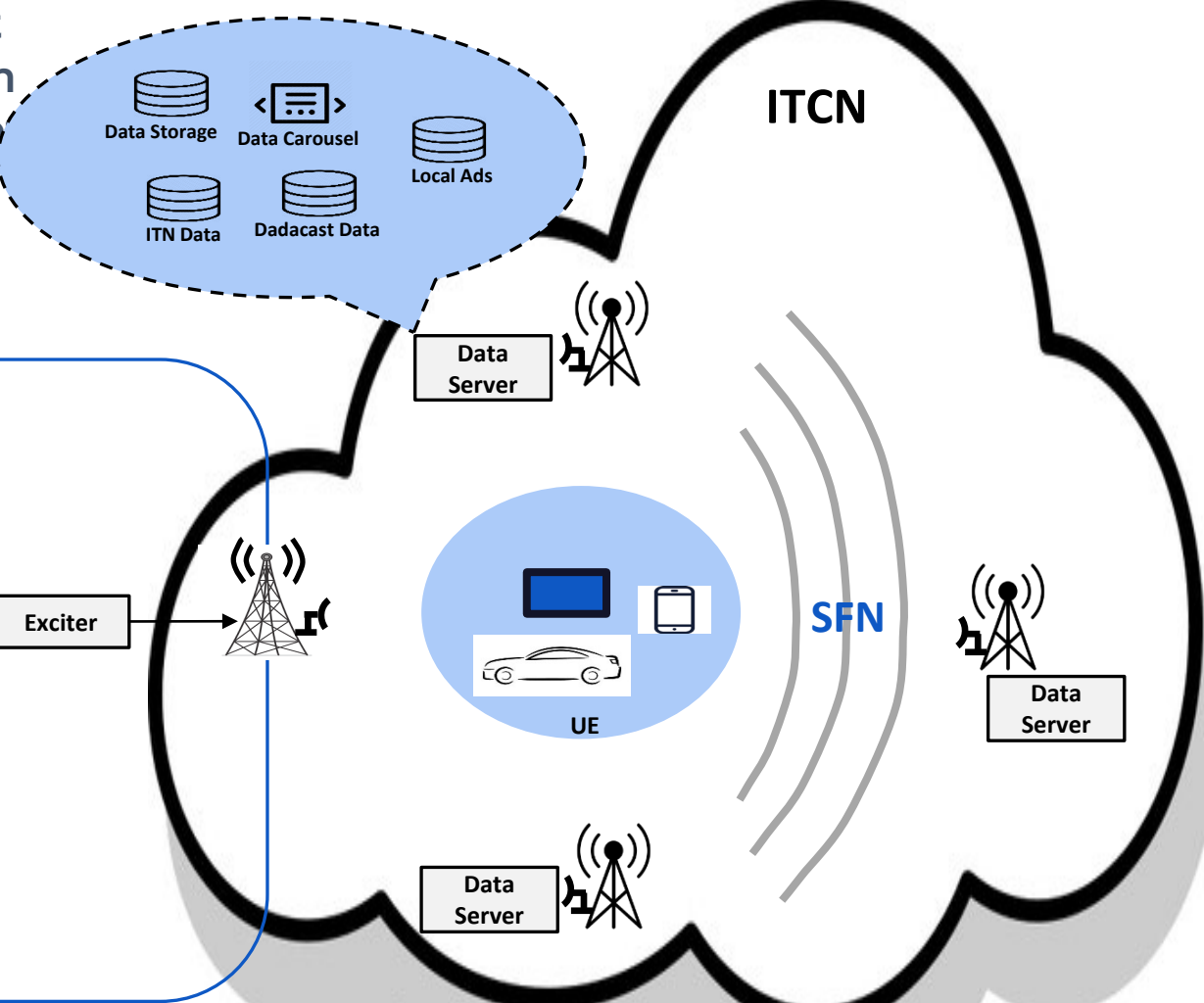
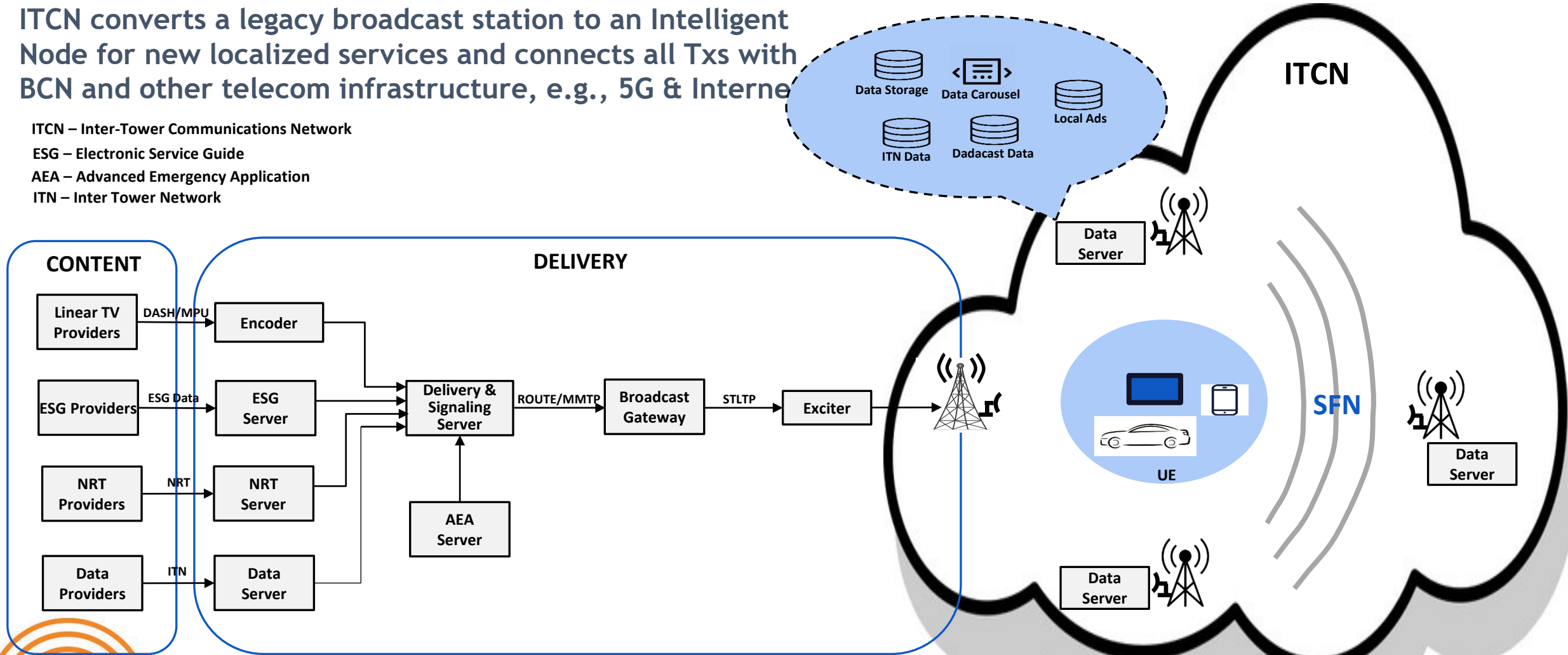
IDL + TWO WAY ITCN + LOCAL ADD CONTENT



The ITCN Big Picture

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

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

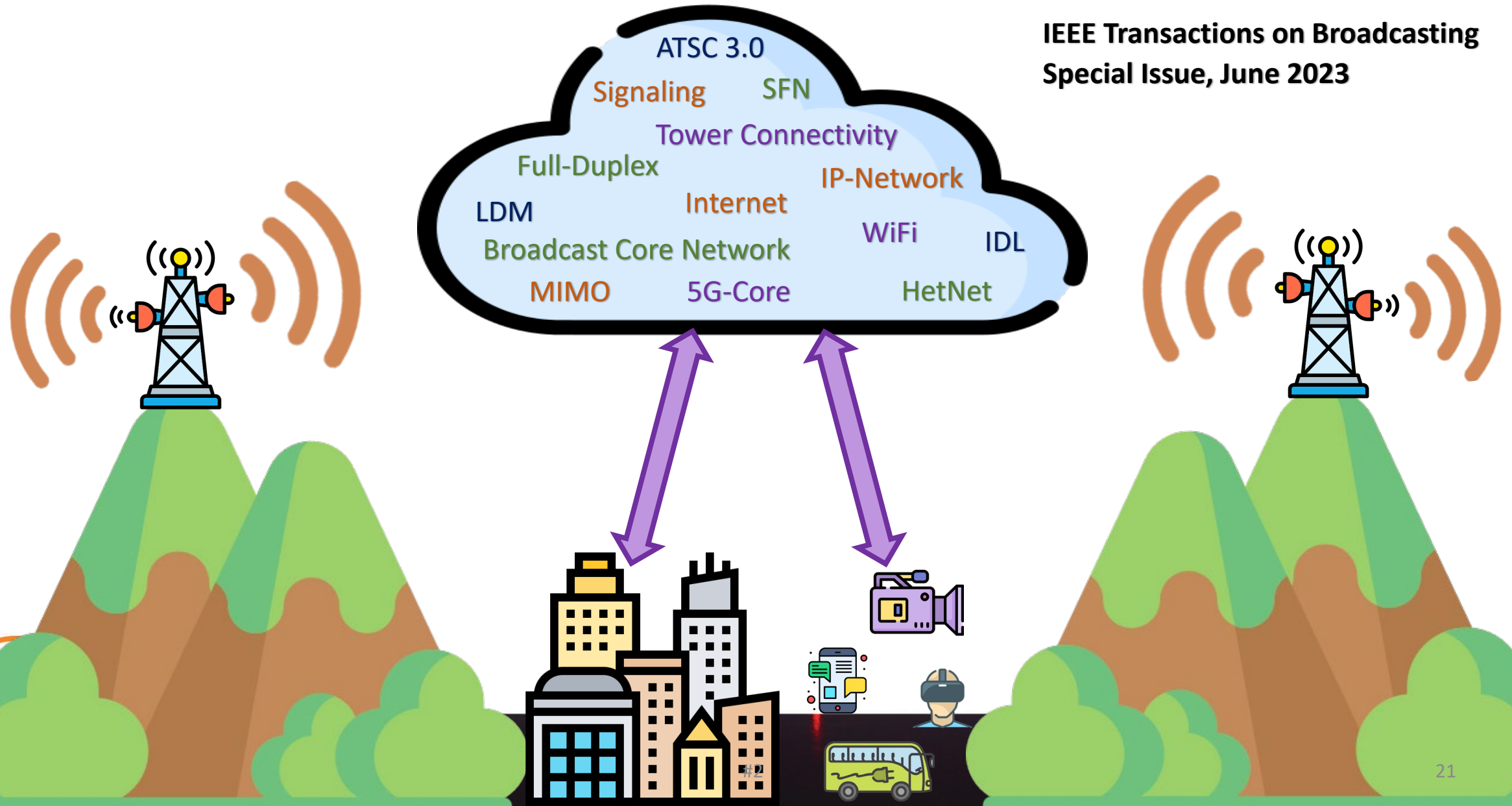


Challenges and Innovations

- Develop a *Broadcast-NodeB* (*bcNB*)
- 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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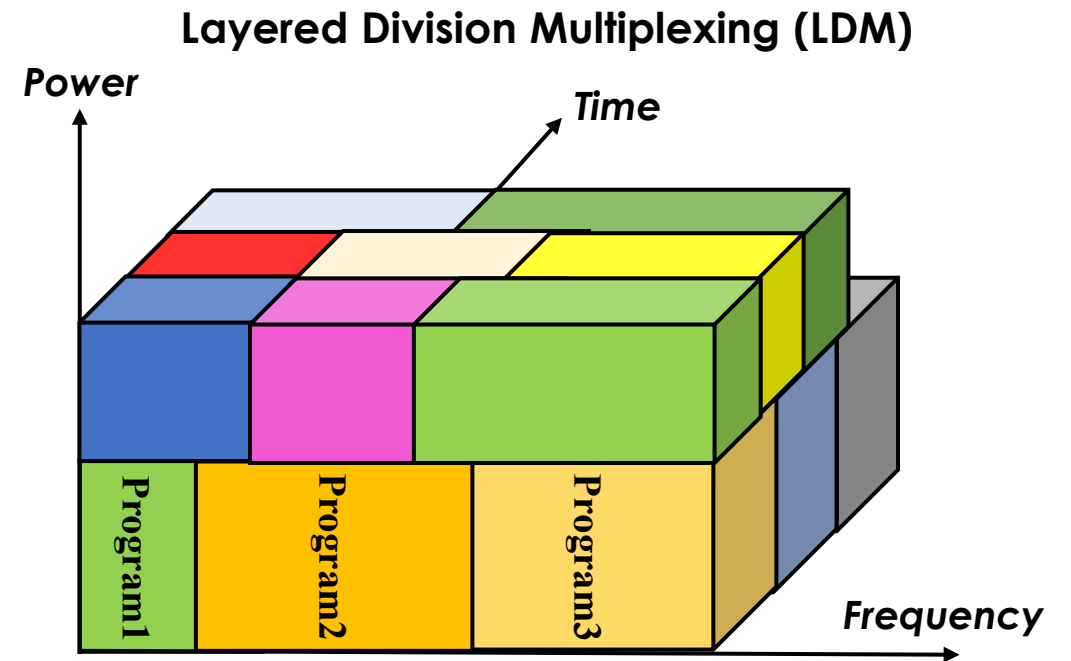
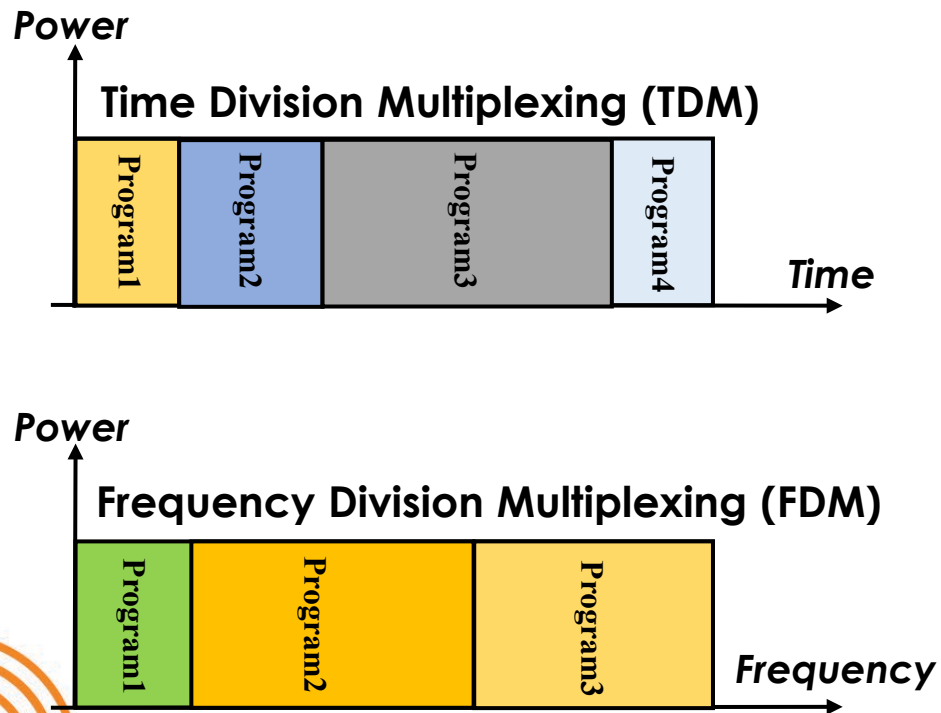
Thank You



LDM: Transmitting

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

Can co-exist with traditional time & frequency division multiplexing



LDM: Receiving

Signal processing technology used to separate layers

Layered Division Multiplexing (LDM)

