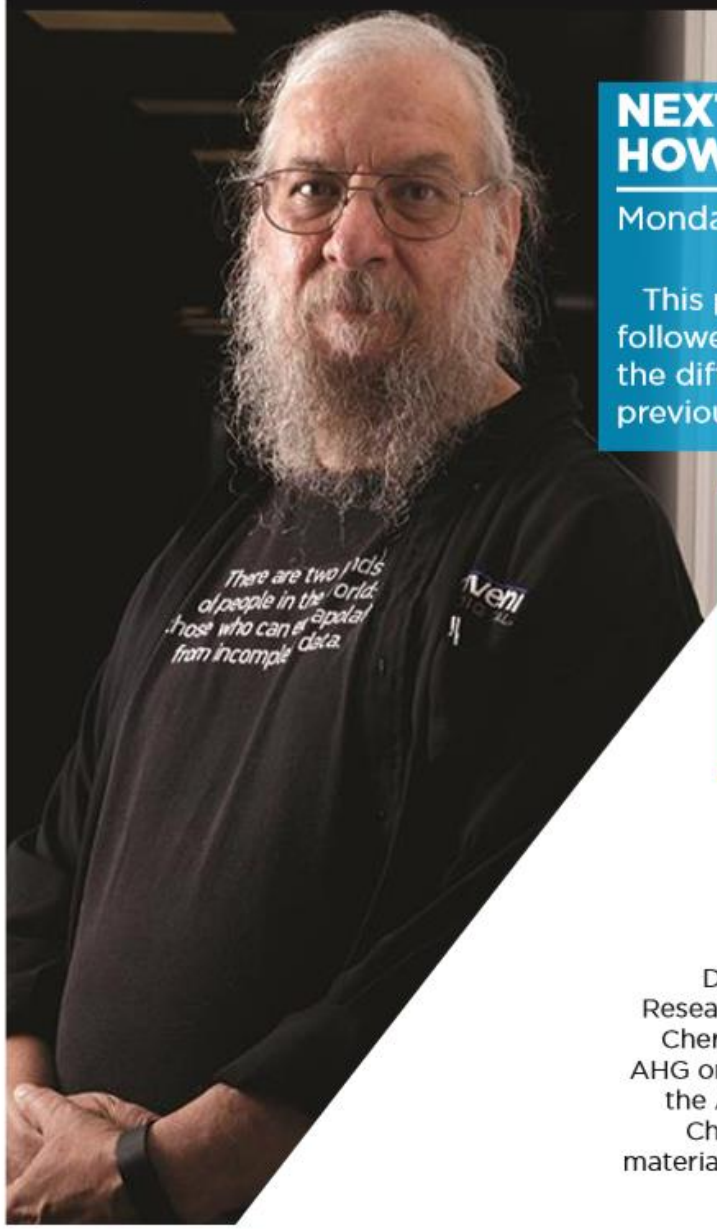
College of
Communication
Arts and Sciences
Michigan State University



NEXT GENERATION BROADCAST TELEVISION: HOW DOES IT WORK?

Monday, Oct. 1 | 10:30 a.m. | Engineering Seminar Room 3540
(on the back side of the Engineering Building)

This presentation will provide an overview of the ATSC 3.0 system, followed by a detailed explanation of the technologies that make up the different layers of ATSC 3.0 and how they have changed from the previous ATSC "1.0" system.

NEXT GENERATION BROADCAST TELEVISION: WHAT CAN WE DO WITH IT?

Monday, Oct. 1 | 3 p.m. | CAS room 182

This presentation will discuss new functionality provided by the ATSC 3.0 broadcast system and potential new services and applications enabled by it.

DR. RICH CHERNOCK

Chief Science Officer at Triveni Digital

Dr. Chernock is currently Chief Science Officer at Triveni Digital. Previously, he was a Research Staff Member at IBM Research, investigating digital broadcast technologies. Dr. Chernock is chairman of the ATSC Technology Group on ATSC 3.0 (TG3) and chairs the AHG on service delivery and synchronization for ATSC 3.0. He was previously chairman of the ATSC Technology and Standards Group (TG1). He is also the Distinguished Lecturer Chair for IEEE BTS. In another life, he used transmission electron microscopy to study materials characteristics for advanced ceramics packaging and semiconductor technology at IBM. His ScD was from MIT in the field of nuclear materials engineering.

Next Generation TV: ATSC 3.0

HOW DOES IT WORK?

OCT 1, 2018

Rich Chernock
ATSC TG Chair Emeritus

IEEE Broadcast Technology Society

IEEE BROADCAST TECHNOLOGY SOCIETY

"THE TECHNOLOGIES TO DELIVER INFORMATION AND ENTERTAINMENT TO AUDIENCES WORLDWIDE, AT HOME AND ON THE GO."

BTS IEEE Broadcast Technology Society

NEXTGENTV

POWERED BY ATSC 3.0

Benefits of IEEE BTS Membership

The BTS is a trans-national Society with over 2000 members and 20 Chapters worldwide. Our Society concerns itself with devices, equipment, techniques and systems related to broadcast technology, including the production, distribution, transmission, and propagation aspects. Our Society is working to advance the professional standing and education of its Members, through our publications, conferences, tutorials and Chapter meetings.

Distinguished Lecturer Program

Mission: To serve the needs of the members of the Broadcast Technology Society to enhance their professional knowledge and vitality by keeping them informed of the latest research results and their practical applications. The BTS Distinguished Lecturer Program exists for the purpose of providing BTS chapters with a list of quality lecturers who can potentially give talks at local chapter meetings, as well as funding to support the travel expenses of the lecturer. The program provides a means for chapters to have access to individuals who are well known educators and authors in the fields of broadcast technology to lecture at chapter meetings.

- DTV & MPEG
- ATSC 3.0
- Display Monitors
- Cameras
- Satellite
- Audio Loudness
- Video & Audio Compression & Coding technologies
- Channel Rate allocation techniques
- 3D TV
- Digital Radio
- Broadcast Regulatory & Legislative Issues
- 8-VSB
- AM, FM, TV antennas
- Image Artifacts
- Directional Pattern design for antennas
- Multimedia Broadcast Services w/ Distributed Transmission Network
- Signal Processing in Broadband Multimedia Communications
- Transmitter ID for Digital Video Broadcast
- SFN, Distributed & Cloud Transmission Systems
- Wind Turbine impact to UHF Band DTV
- Video Streaming w/Multiple Description Coding & Network Diversity
- Temporal Dependant Rate Distortion Optimization in Motion Compensated Video Coding

- USA
- UK
- Canada
- France
- Italy
- Singapore
- Argentina
- China
- Spain
- Korea
- Malaysia

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IEEE Broadcast Technology Society

TODAY

NEXTGENTV

POWERED BY
ATSC 3.0

ATSC 3.0 Participation

373 individuals on reflector/document system

- Many others focused on 3.0 development efforts

150 organizations

- Broadcasters
- Consumer Electronics Manufacturers
- Professional Equipment Manufacturers
- R&D Laboratories
- Universities

International Participation

- Canada
- China
- Europe (including DVB)
- Japan (including NHK)
- South Korea
- United States

Goals of ATSC 3.0

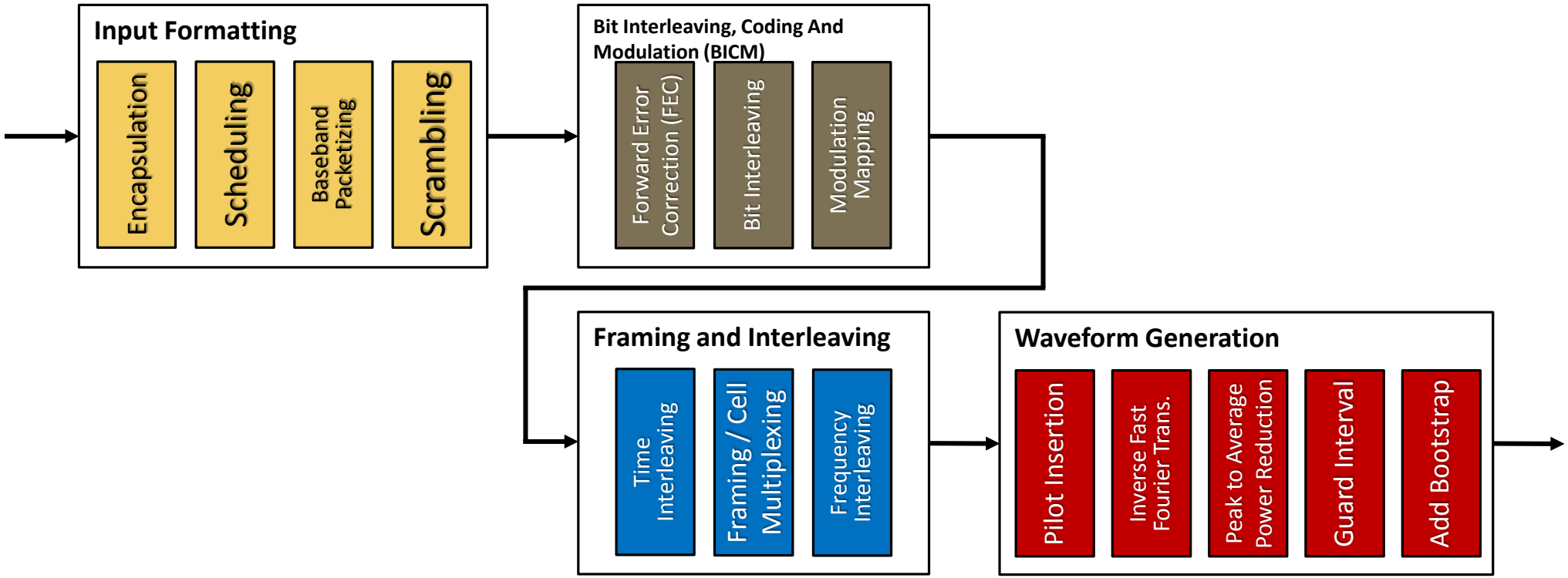
To add value to the broadcasting service platform	Enables new business models	Reaches more viewers on more devices
To address changing consumer behavior	Provides higher quality audio and video, more accessibility	Watch what you want, when you want, where you want

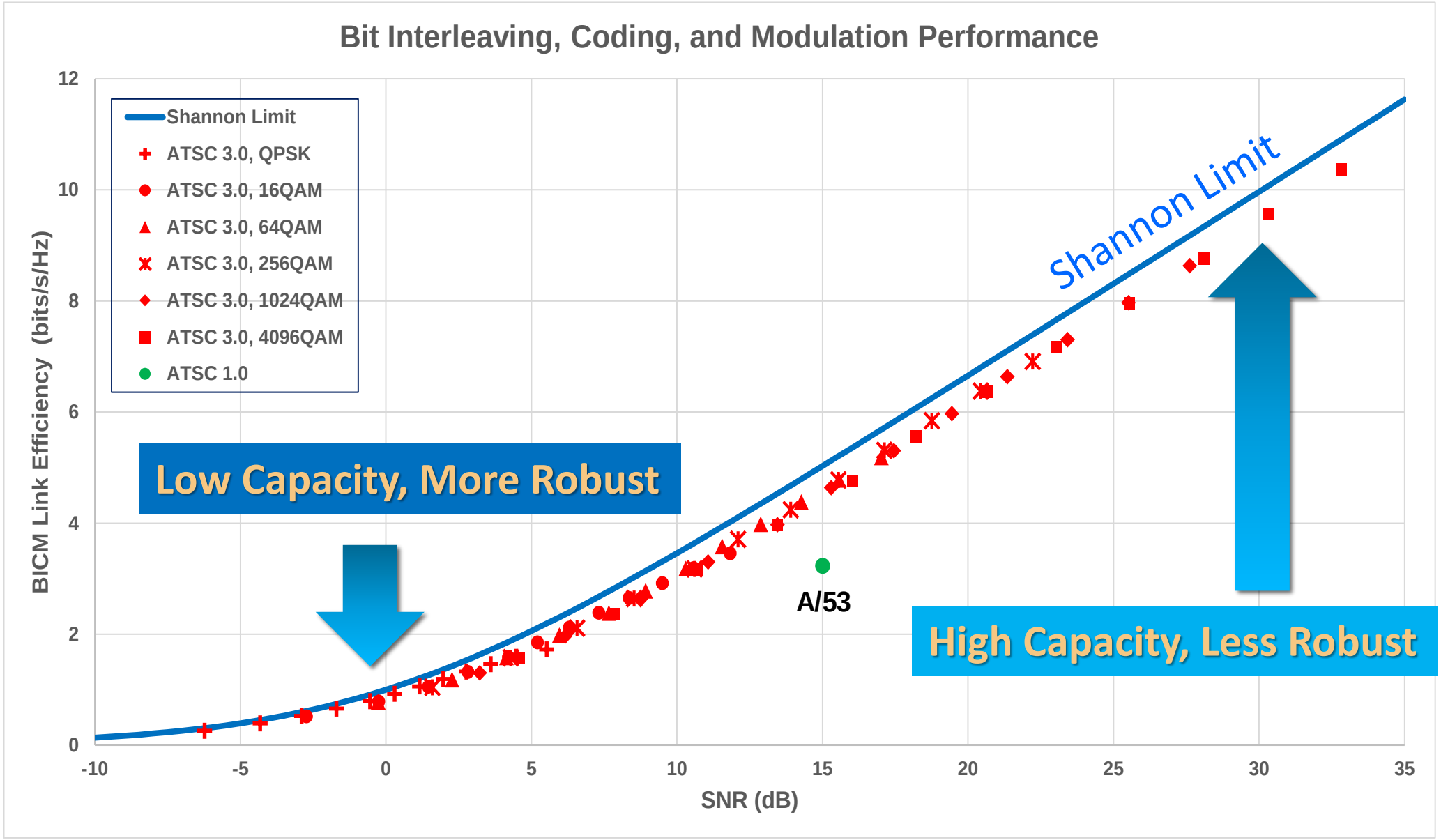
Key Advancements in 3.0

- **Additional capacity** — More channels, more pixels
- **Better reception** — Indoor, moving vehicles, handheld/ mobile devices
- **Integrated OTA and OTT delivery**
- **Enhanced consumer experience** — Improved video and audio quality; Lots of choices; Interactivity; Advanced emergency and accessibility features
- **New business models** — Advanced advertising; PPV and subscription services; Service usage reporting; Datacasting

ATSC 3.0 Physical Layer and Transport Layer

Physical Layer Architecture




Bit Interleaving, Coding, and Modulation Performance
BICM Link Efficiency (bits/s/Hz)
SNR (dB)
Shannon Limit
ATSC 3.0, QPSK
ATSC 3.0, 16QAM
ATSC 3.0, 64QAM
ATSC 3.0, 256QAM
ATSC 3.0, 1024QAM
ATSC 3.0, 4096QAM
ATSC 1.0
Low Capacity, More Robust
High Capacity, Less Robust
A/53
Shannon Limit
0
2
4
6
8
10
12
-10
-5
0
5
10
15
20
25
30
35

Frame Hierarchy for Payload

Frames

- The largest physical layer container for carrying data traffic is a physical layer frame

Subframes

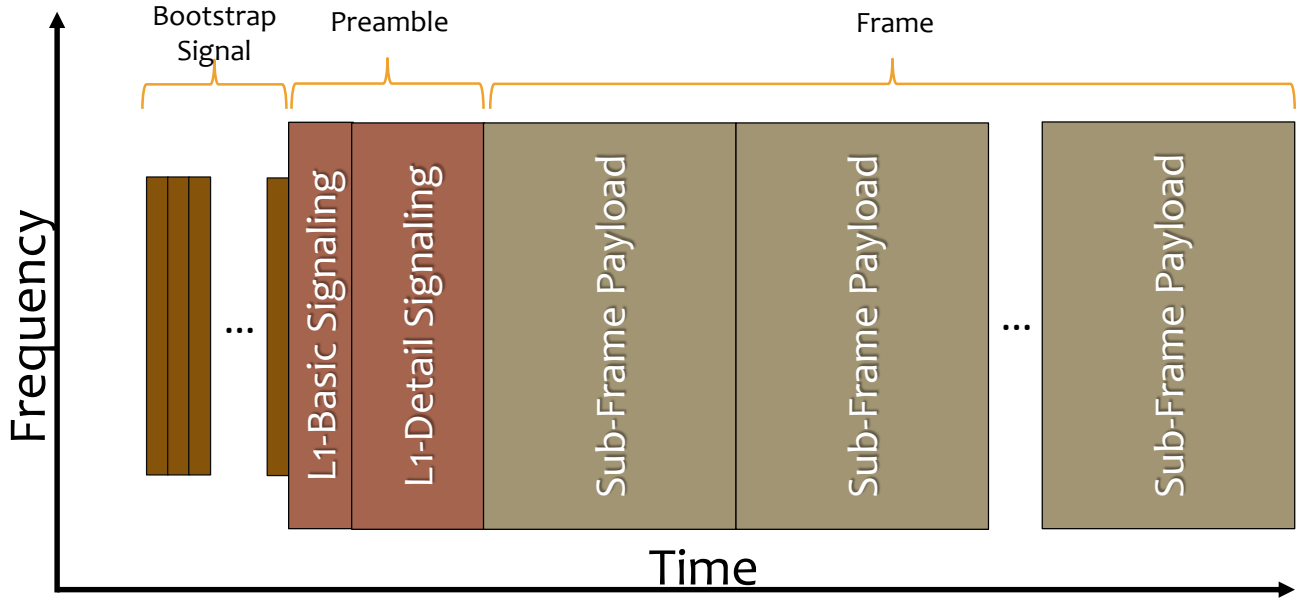
- Each frame contains one or more subframes
- Each subframe is associated with a subframe type, which is a function of the OFDM configuration parameters for that subframe
- Subframes within the same frame can have the same or different type

Physical Layer Pipes (PLPs)

- Each subframe contains one or more physical layer pipes which carry actual payload data
- A PLP's throughput capacity depends on: Forward Error Correction (FEC) code rate, modulation order, and number of allocated cells
- Multiple PLPs for different services can share the same subframe
- Maximum of 64 distinct PLPs in an RF channel; maximum of 4 PLPs in a given service

Signaling Hierarchy

A frame consists of bootstrap, preamble, and data portions



- The bootstrap serves as the robust universal entry point to a waveform and signals parameters that enable decoding of L1-Basic
- L1-Basic signals parameters that enable the decoding of L1-Detail and the initial processing of the first subframe.

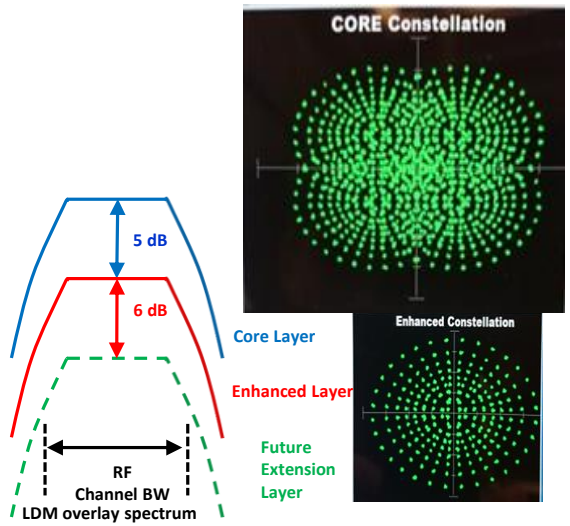
Layer Division Multiplexing (LDM)

Layer Division Multiplexing (LDM) is based upon the superposition of two signals operating at different amplitude (power) levels.

LDM Capable Receiver is able to “subtract” the core layer to decode the enhanced layer

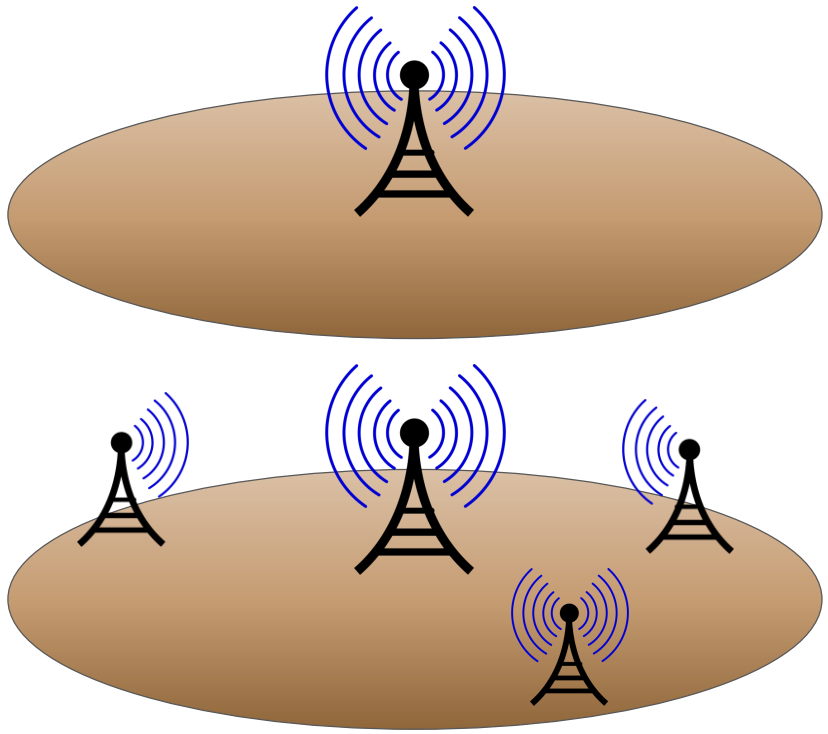
LDM provides large “gain” in transmission efficiency

Time Division Multiplexing (TDM), Frequency Division Multiplexing (FDM) along with LDM are all possible



Single Frequency Networks

Single stick antenna may result in coverage holes with lower SNR due to problematic propagation conditions



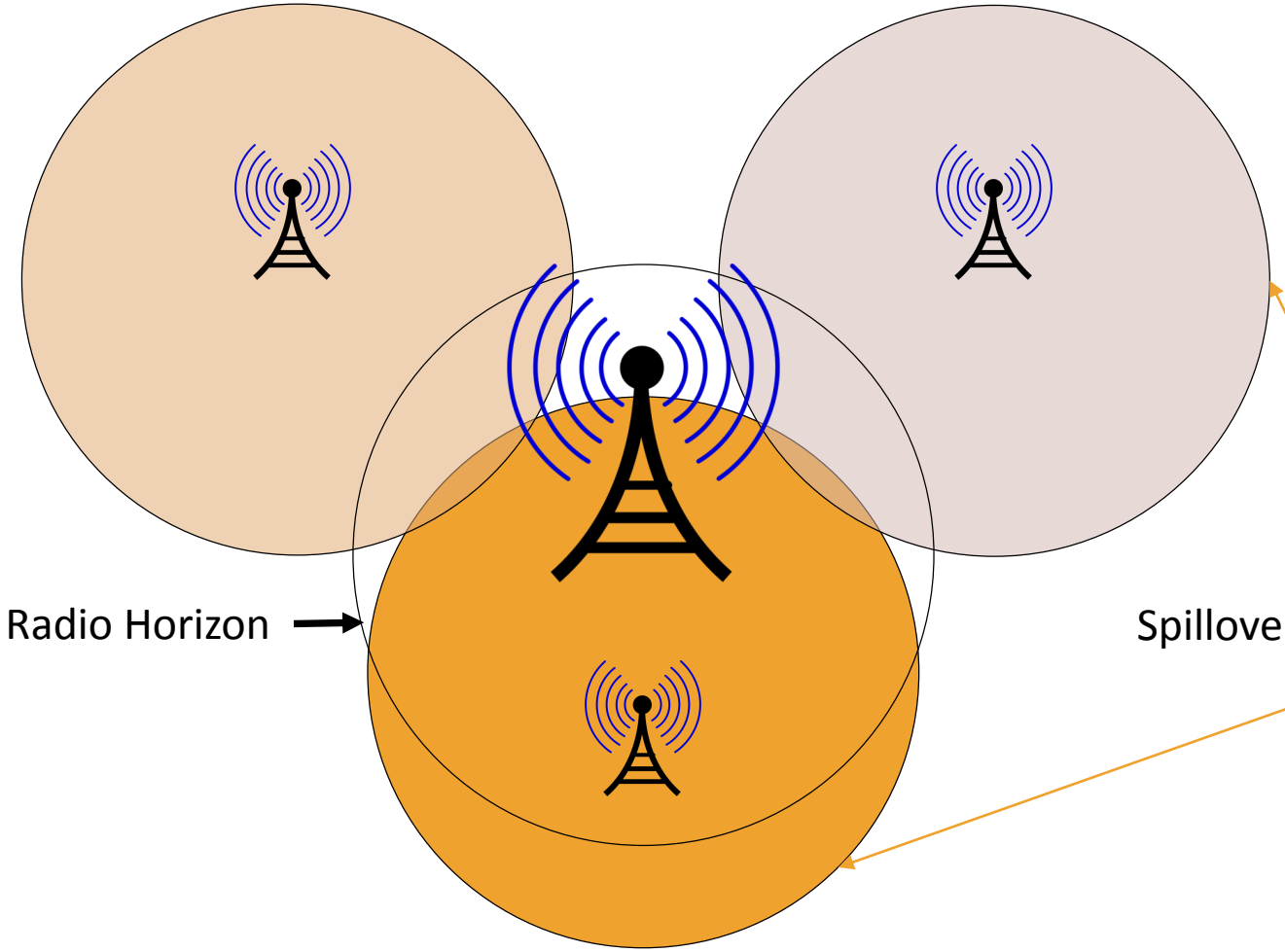
SFN with multiple transmitters increases coverage by boosting SNR in coverage holes

Multiple transmitters in an SFN can be used to extend coverage and add capacity by raising SNR.

OFDM (Orthogonal Frequency Division Multiplexing) guard interval alleviates potential inter-symbol interference arising from multiple transmitters.

MISO (Multiple Inputs, Single Output) can be used to artificially decorrelate signals from multiple transmitter to avoid destructive interference.

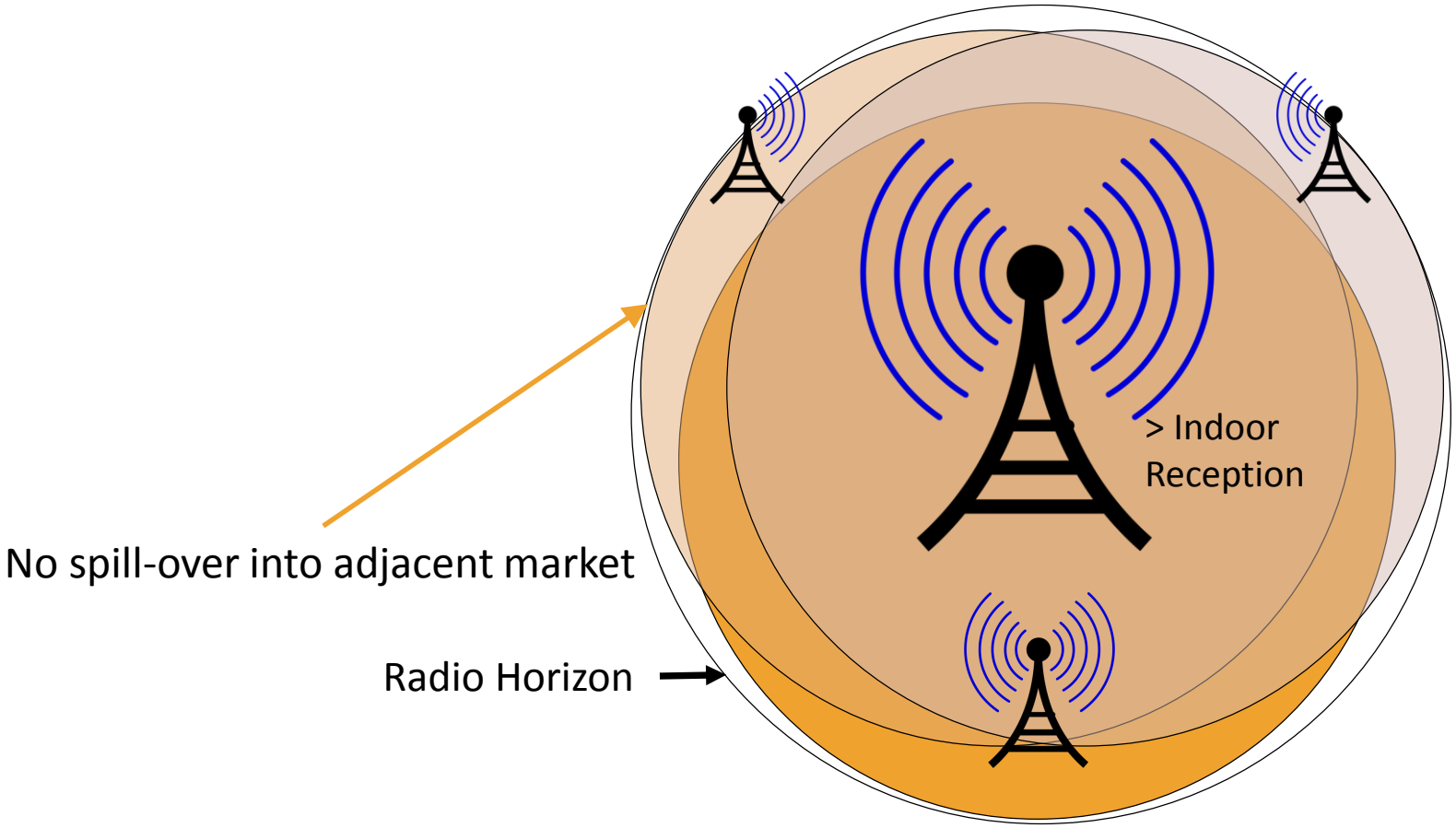
Single Frequency Network (1)



This set-up can be used to enable continuous service from one DMA to another

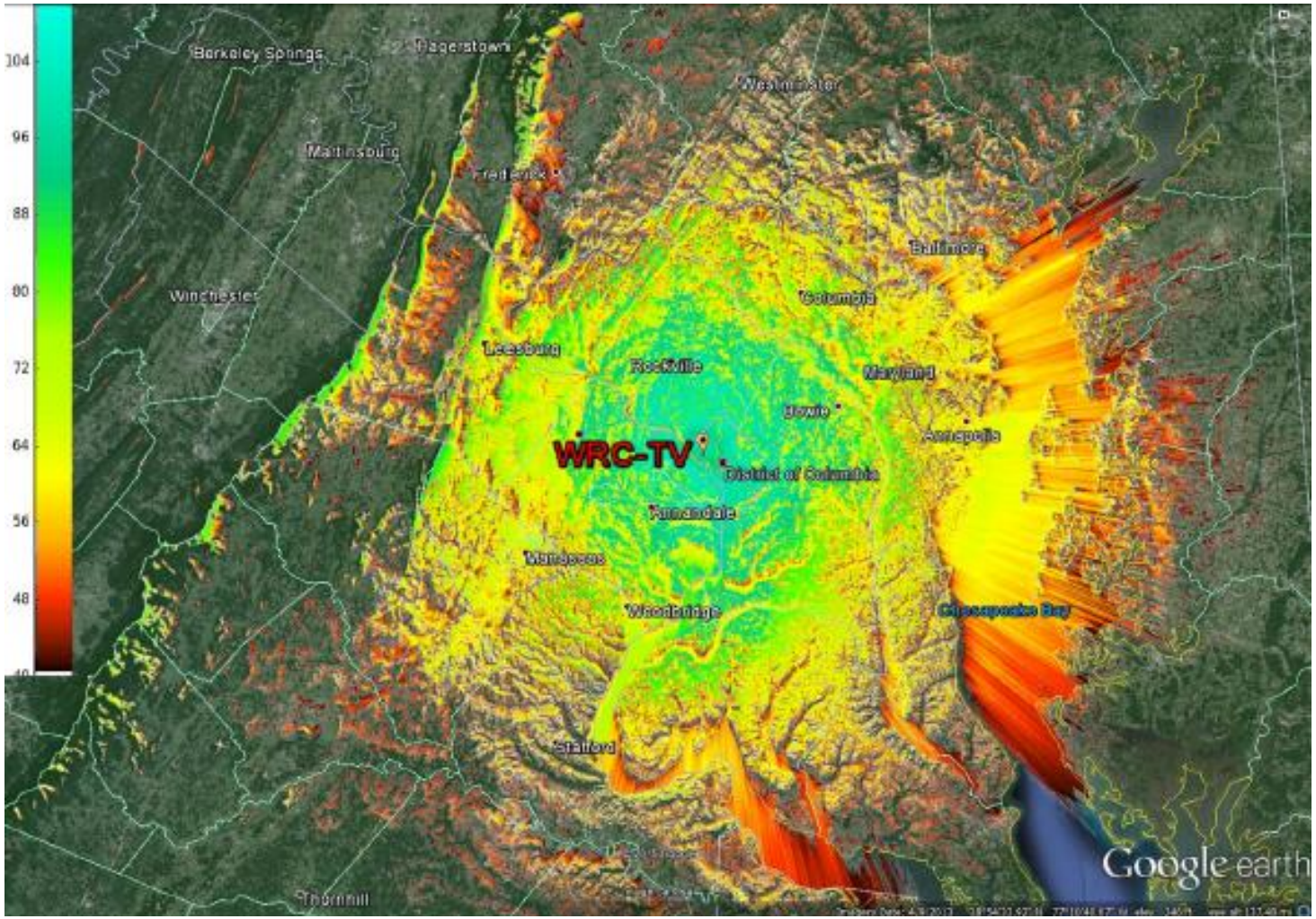
Spillover into adjacent market

Single Frequency Network (2)

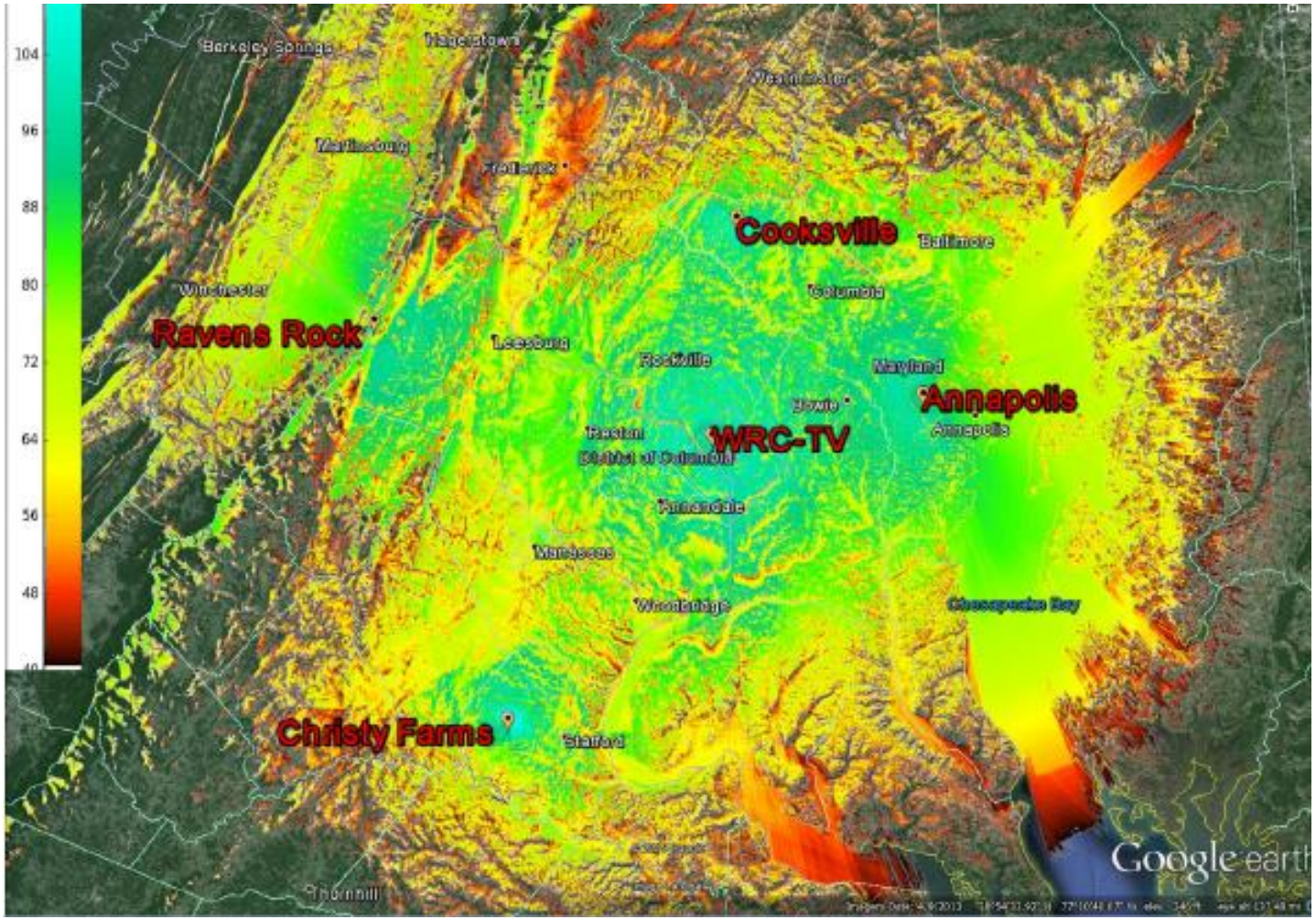


This set-up can be used to increase coverage in a given DMA

Washington, DC without SFN (example)



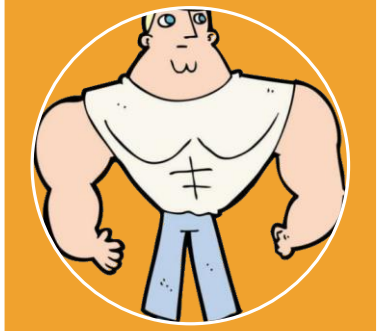
Washington, DC with SFN (example)



Physical Layer Benefits

The ATSC 3.0 suite of standards enables many system options for the broadcasting industry

Hierarchical control signaling of parameters provides robust yet efficient communication of waveform configuration



High robustness, spectrally efficient operating points

Flexible configuration of operating modes with large SNR range

Very robust synchronization with signaling of basic system parameters to allow for future technology advances

Many flexible functions (framing, time interleaving, etc.) for optimization per broadcaster

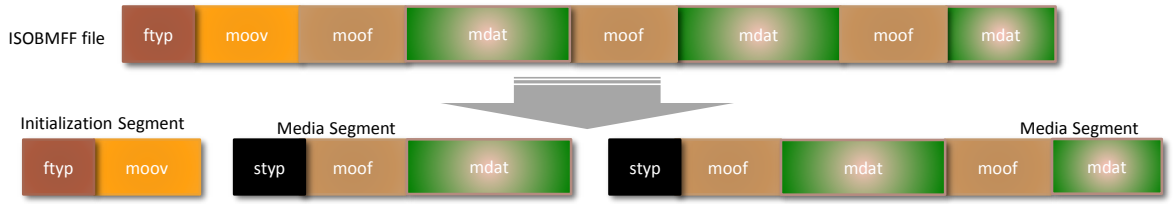
Transport – the 3.0 system "plumbing"

- DTV is made up of numerous objects & streams
  - Content elements
  - Files
  - Metadata BLOBs
- Need to segment into usable-sized pieces
  - and reassemble at the other end
- Need to associate components with services
- Need to be able to synchronize components
  - Independent of delivery mechanism

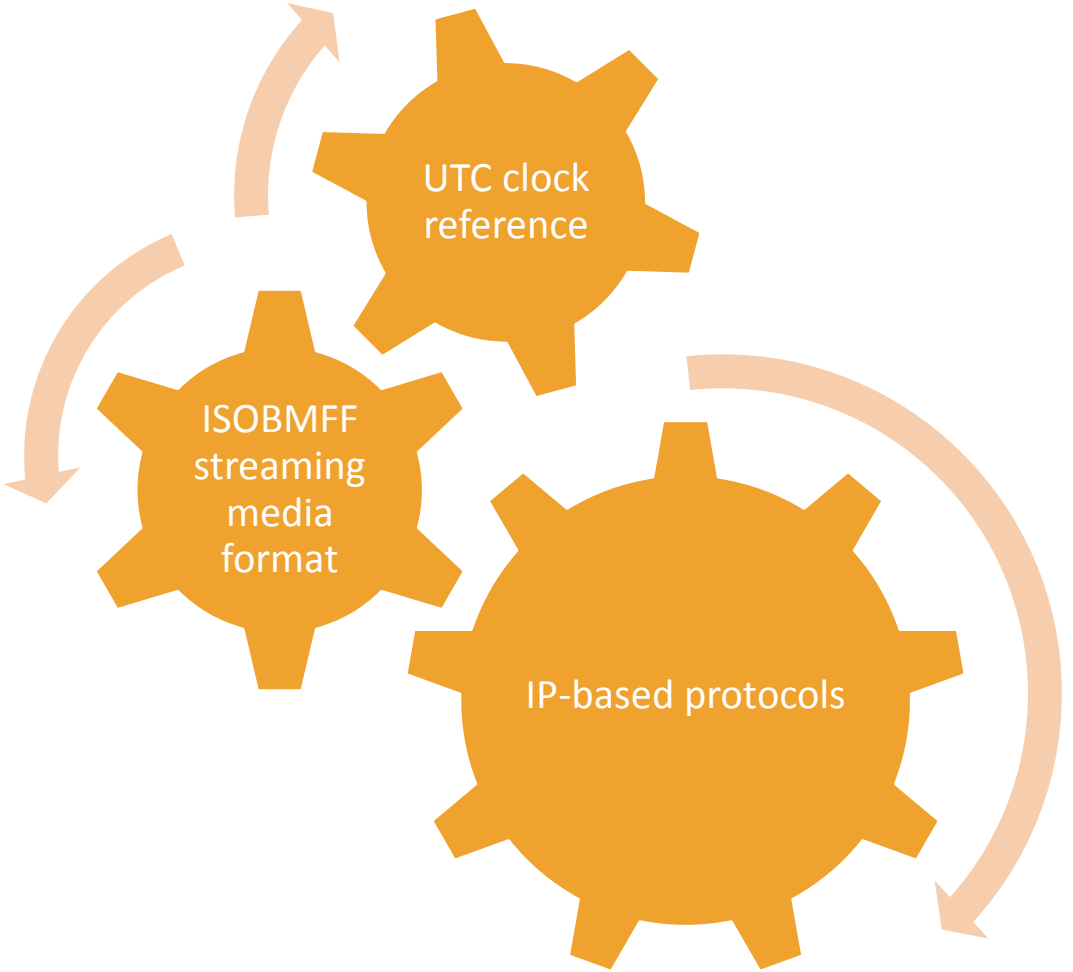
Transport Layer Key Elements

Common elements include

- Use of IP Transport for broadcast delivery
- Use of ISOBMFF as a content format for streaming delivery



- Use of UTC for synchronization and buffer management
  - All elements of the system "know what time it is"



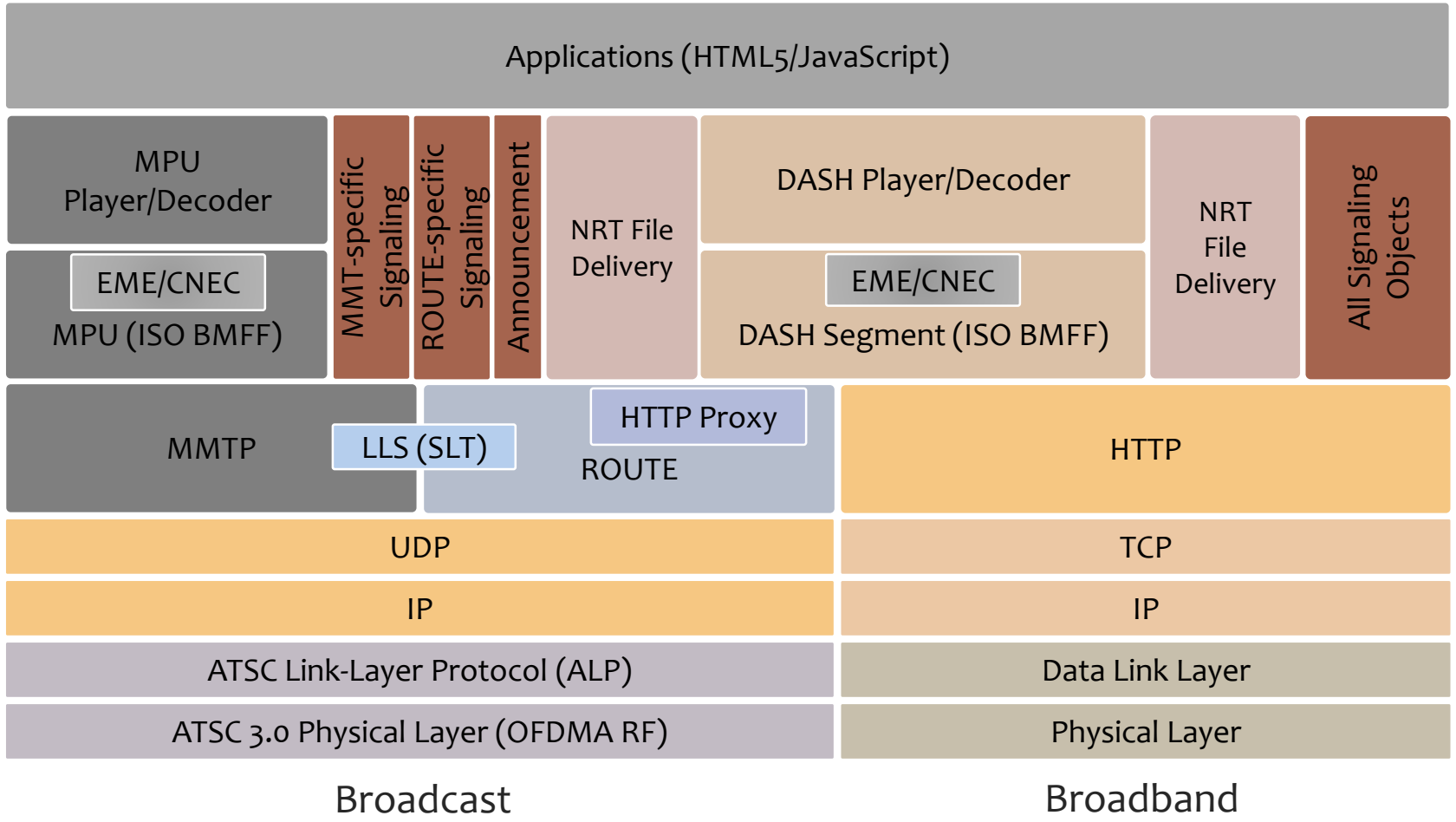
ATSC 3.0 Transport Layer

The ATSC 3.0 Management and Protocols Layer encompasses

- Service delivery and synchronization
- Service announcement and personalization
- Interactive services and companion screens
- Redistribution support / watermarks

IP Transport is used for delivery of both OTA and OTT content

The use of IP transport is a game-changer for broadcasting



Transport – the 3.0 system "plumbing" (comparison)

- DTV is made up of numerous objects & streams ← No change
  - Content elements
  - Files
  - Metadata BLOBs
- Need to segment into usable-sized pieces ← IP Packets vs MPEG-2 TS packets
  - and reassemble at the other end
- Need to associate components with services ← IP Address/Port vs PIDs
- Need to be able to synchronize components ← Universal System time vs STC established via PCRs
  - Independent of delivery mechanism

ATSC 3.0 Video System

ATSC 3.0 Video

Resolutions up to 3840 × 2160

Spatial scalability (SHVC)

High Frame Rate

- Up to 100, 120, 120/1.001 (plus lower framerates)
- Temporal sub-layering enables backward compatibility
- Plus temporal filtering for optimizing both the SFR and HFR pictures

High Dynamic Range

- PQ & HLG transfer functions (plus SDR)
- Metadata for PQ

Wide Color Gamut

- Wide Color Gamut BT.2100 (plus BT.709 for SDR)
- $Y'C_BC_R$ non-constant luminance
- IC_TC_P constant luminance (for PQ)
- Full Range coding (for PQ)
- SL-HDR1 for delivering SDR/709 stream that SL-HDR1-capable decoders can render as HDR/2020

Legacy and Progressive Video Formats

Legacy Interlace Video Formats

- SD: {640,704,720}x480
- HD: {1440,1920}x1080

Progressive Video Formats

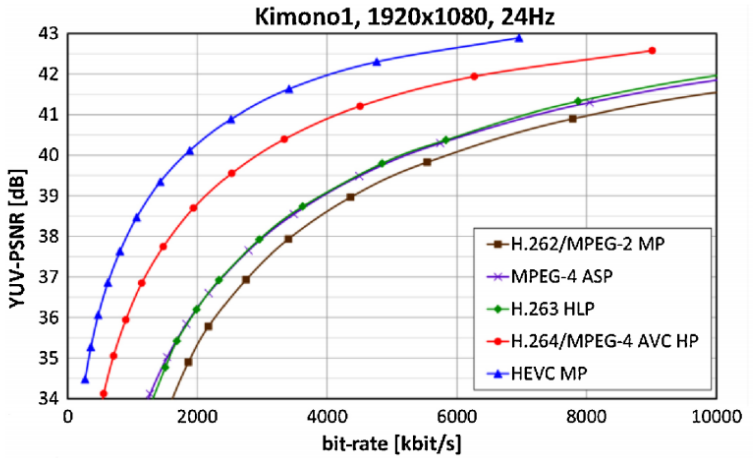
- Resolutions: 16:9/square pixels, divisible by 8 in both dimensions, up to 3840x2160
- HDR, WCG, HFR, 4K, Scalable, etc. are only supported for progressive formats

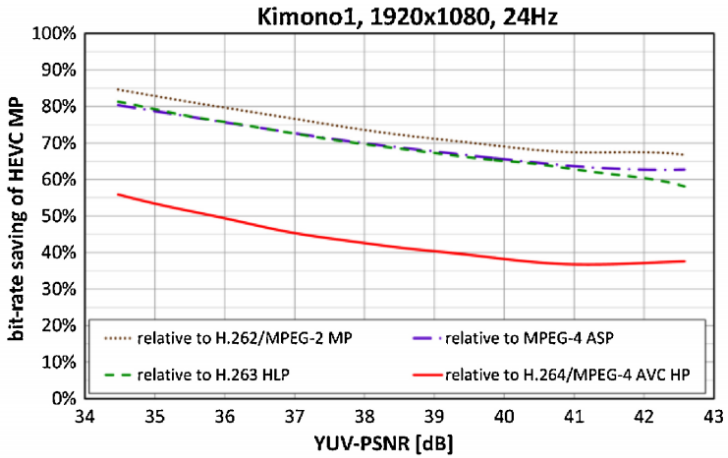
HEVC

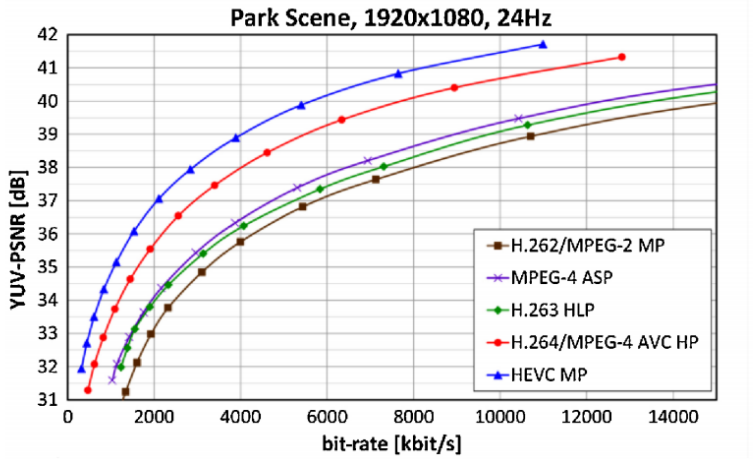
HEVC Main 10 Profile specified

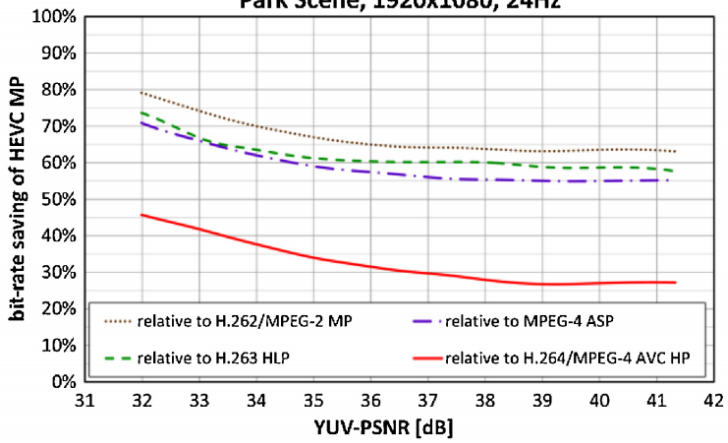
35-50% performance gains vs. AVC/ H.264

10-bit codec is required for HDR



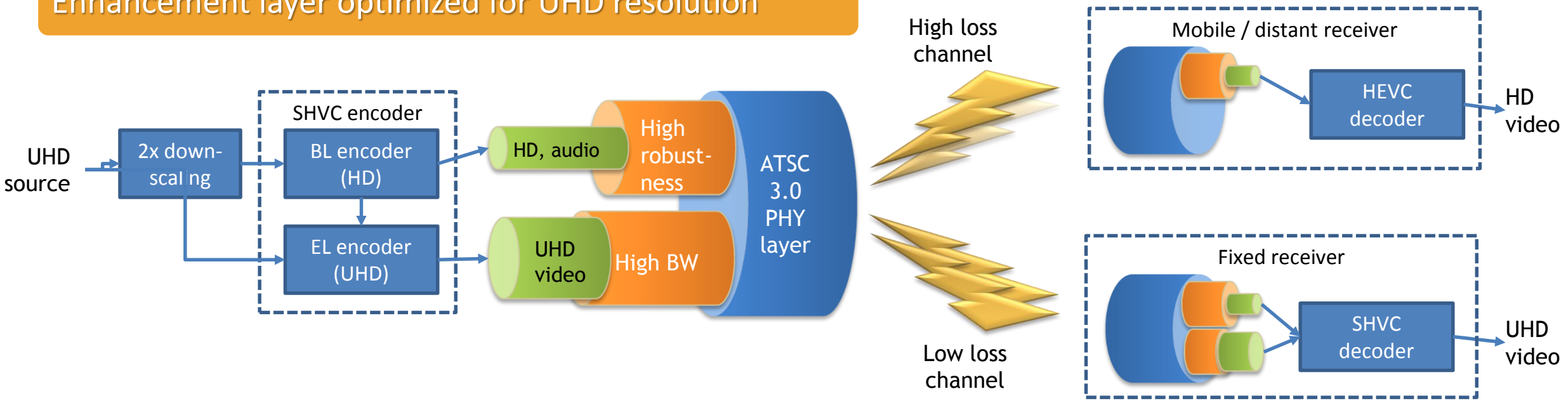




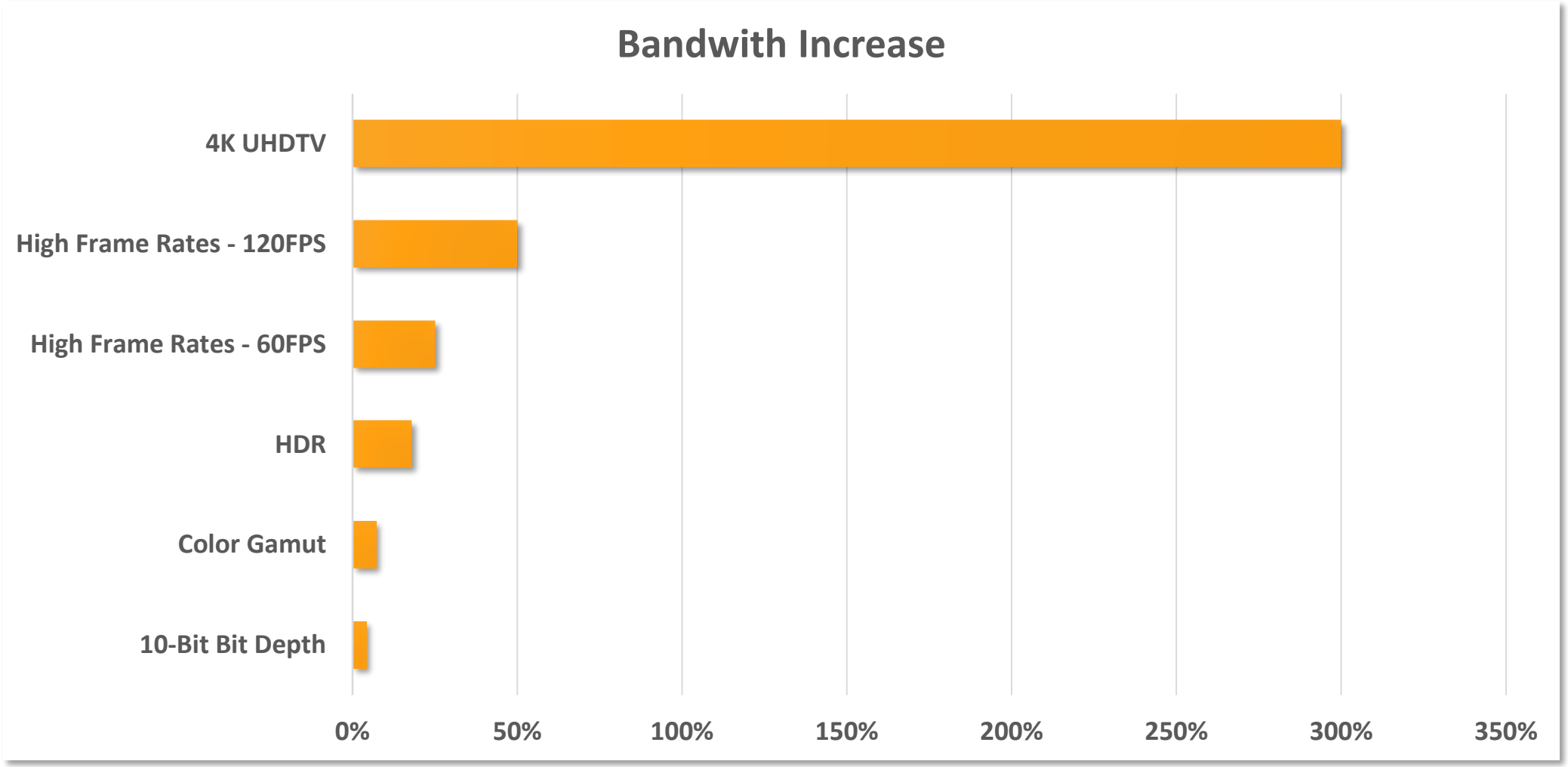


SHVC: Spatial Scalability

- Limited to 2 spatial layers
- Base layer optimized for mobile reception
- Enhancement layer optimized for UHD resolution



HDR/WCG: “Good Bang For The Bit”



ATSC 3.0 Audio System

ATSC 3.0 Audio Systems

2 audio technologies are standardized in the ATSC 3.0 suite

Dolby AC-4

MPEG-H AUDIO ALLIANCE

The Next-Generation System for Interactive and Immersive Sound

1 technology per country or region

- **Dolby AC-4 for use in the U.S.**
- **MPEG-H in South Korea**

Audio: Personalization

Choose language

Choose commentary

Address impairments with description and improved intelligibility

Normalize loudness of all content

Contour dynamic range to the unique user, device and environment

Immersive, Enhanced Surround Sound

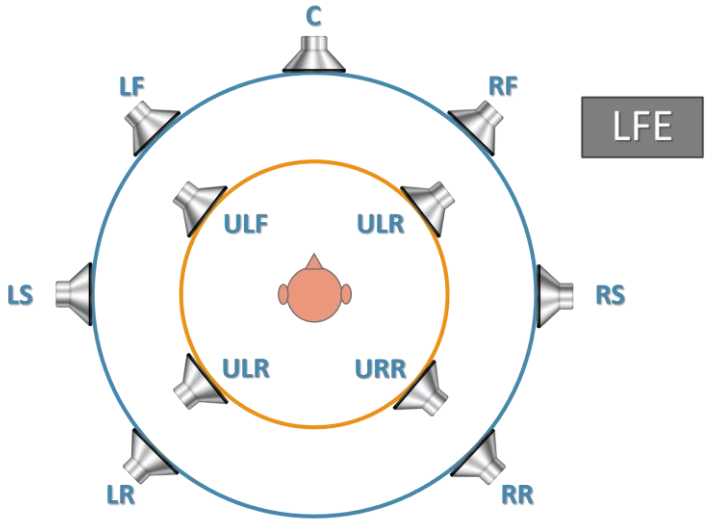
Improved spatial resolution in sound source localization

- Sound with improved azimuth, elevation and distance perspective
- Use of channels and objects or “elements” and metadata (similar to fader automation)
- Metadata allows rendering at the decoder, customized to the user’s sound system
- The decoder places the sound in the most accurate position the user’s sound system supports

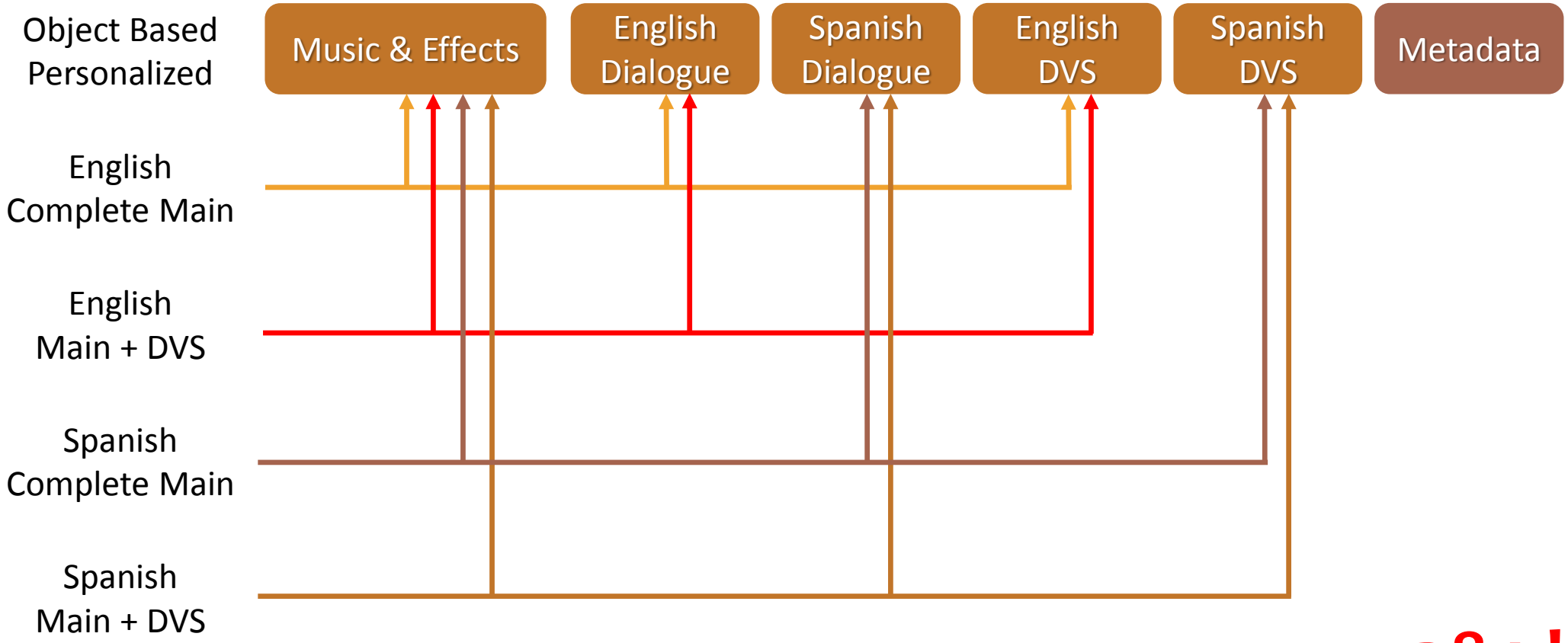
Rendering for Headphones

Headphone Reproduction Will Simulate Height & Depth –

Sounding more like speakers and the feeling of listening in a room



Transmitting Audio



4 Complete Presentations at ~ 384kbps

384 kb/s!

Dolby Laboratories

ATSC 3.0 Accessibility

What is Accessibility in ATSC 3.0?

- **Emergency Alerts & Messaging**
  - Emergency Crawls & Audio Tracks
- **Visually Impaired**
  - Video Description
- **Hearing Impaired**
  - Closed Caption
  - Closed Signing
  - Dialog Intelligibility

Visually Impaired

ATSC 1.0 requires VD to be sent as a secondary audio program typically mono or stereo mix down with narration.

ATSC 3.0 allows VD object element to be broadcast in audio stream and mixed in with music, dialog and effects with minimal effect on broadcast capacity while providing a better experience to audience.

Aural renderings of emergency messages can also be an object element

In both cases multiple versions are possible (e.g., alternate languages)

Hearing Impaired

Caption Stream

- Mandatory
  - IMSC1 via broadcast
- Optional
  - IMCS1 via broadband (e.g. alt. language)
  - 608/708 in the video SEI

Dialog Intelligibility

- In ATSC 1.0 the mix cannot be easily modified.
- In ATSC 3.0 the dialog can be maintained as a separate element.

Closed Signing

- Interactive standard enables Picture in Picture
- PiP can be used for sign language that can be toggled on/off like captions

What is IMSC1?

- W3C's "TTML Text and Image Profiles for Internet Media Subtitles and Captions"
- "IMSC1" – is a well defined profile specifically targeted at closed captions and subtitles.
- Supports world-wide language and symbol tables.
- Supports world-wide image glyph delivery.
- Supports FCC requirements for both 708 and IP captions.
- US FCC safe harbor for IP-delivered content.
- Supports ATSC 3.0 Hybrid delivery of broadcast and broadband.

ATSC 3.0 Interactivity

ATSC 3.0 Interactive Content – Key Features

- Describes the conceptual application operating environment
- Standard W3C User Agent – HTML5, CSS & JavaScript
- Supports seamless, secure delivery of interactive content from broadcast and broadband
- Provides a separate, unique context for each application
- Defines a WebSocket API to manage the receiver features

Foundation 1: HTML5

HTML5: HyperText Mark-up Language, version 5

- Current Web Standard

Simple Language: Elements (tags), Attributes, and Text

- Refers to other pages and content using URLs
- My Web Site

Elements can be nested

```
<a href="http://www.xbc.com/somepage.html">
        <img class="someClass" source="images/myicon.png" title="A ToolTip" border="0"
        width="16px" height="16px" />
</a>
```

HTML5 Pages are loaded into User Agents (e.g. Browsers)

- Loaded pages are represented in a Document Object Model (DOM)
- The DOM provides data and built-in APIs for JavaScript manipulation

Foundation 1a: CSS – Cascading Style Sheets

Separates presentation and content, including aspects such as the layout, colors, and fonts

Removes the need to define styles on every element

Allows HTML5 pages to be ‘Skinned’

Styles have selectors that can associate the style with elements, classes or patterns of elements

Simple language with big power

- a {
  color: #377049; font-weight: bold;
  }

Foundation 2: JavaScript

High-level, dynamic, untyped, and interpreted run-time language

- Standardized in the ECMAScript language specification

The Language of the Broadcaster Application

- HTML5 & CSS describe data
- JavaScript codifies logic that manipulates that data

```
<button id="hellobutton">Hello</button>
  <script>
    document.getElementById( 'hellobutton‘ ).onclick = function() {
      alert('Hello world!');                  // Show a dialog
      var myTextNode = document.createTextNode('Some new words.');
      document.body.appendChild(myTextNode);     // Append "Some new words" to the page
    };
  </script>
```

Interactivity – Example

When a goal is scored, an event can be sent to the app causing celebration graphics to appear.

ADVANCED EMERGENCY ALERTS

What is Advanced Emergency Alerting?

Enables broadcasters to deliver a rich set of data and media to viewers or non-public audiences

- Text, images, video, interactive interfaces
- Viewer can dismiss messages (unlike “burned-in” crawls)

Supplements, enhances, but doesn’t replace EAS

Possibility of geo-targeting

- For receivers that “know where they are”

Possibility of waking up devices in stand-by mode

Possibility of targeting (and encrypting) messaging for groups (first responders, gov’t, business…)

AEA Wake-up Function

The Bootstrap is the initial discovery and entry point in the ATSC 3.0 waveform

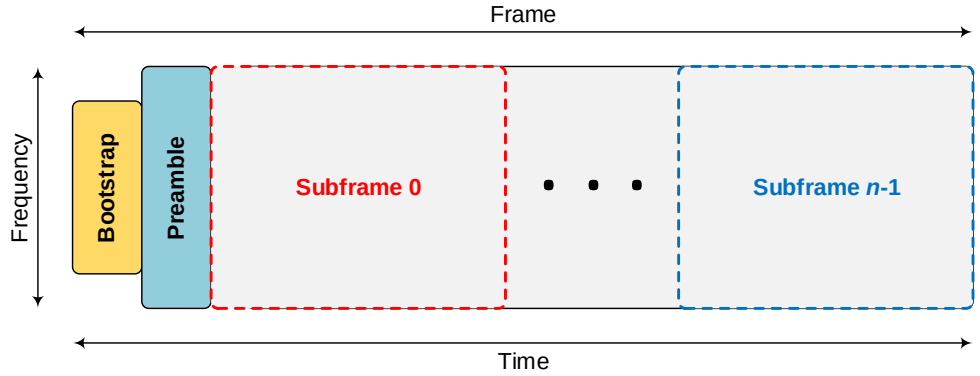
Wake-up Field is comprised of two bits in the Bootstrap

Two bits = 4 wakeup states…one negative and 3 positive

- Change in state is what matters
- Designed to avoid nuisance factor and extend battery life

Note that there is one Bootstrap per RF band

- Broadcasters that are channel-sharing must coordinate use of the wake-up bits



Value	Meaning
'00'	No emergency to wake up devices is currently signaled
'01'	Emergency to wake up devices - setting 1
'10'	Emergency to wake up devices - setting 2
'11'	Emergency to wake up devices - setting 3

Advanced Emergency Alert Table

- AEAT contains the elements and attributes of the emergency messages

Who gets it

When

Alert Summary

Where

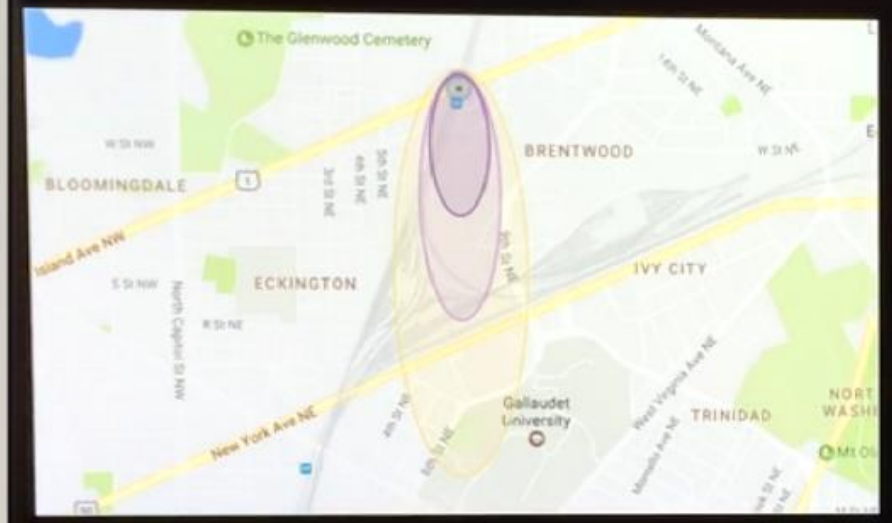
Alert Narrative

Live Media

File-based Media

Element or Attribute Name	Use	Data Type	Short Description
AEAT			Root element of the **AEAT**
AEA	1..N		Advanced Emergency Alert formatted as AEA-MF.
@AEAid	1	string	The identifier of AEA message.
@issuer	1	string	The identifier of the broadcast station originating or forwarding the message.
@audience	0..1	string	The intended distribution of the AEA message.
@AEAtype	0..1	string	The category of the message.
@refAEAid	0..1	string	The referenced identifier of AEA message. It shall appear when the `@AEAtype` is "update" or "cancel".
@priority	1	unsignedByte	The priority of the message
Header	1		The container for the basic alert envelope.
@effective	1	dateTime	The effective time of the alert message.
@expires	1	dateTime	The expiration time of the alert message.
EventCode	1	string	A code identifying the event type of the AEA message.
@type	0..1	string	A national-assigned string designating the domain of the code (e.g. SAME in US, …)
EventDesc	0..N	string	The short plain text description of the emergency event (e.g. "Tornado Warning" or "Tsunami Warning".
@lang	1	string	The code denoting the language of the respective element of the `EventDesc`
Location	1..N	string	The geographic code delineating the affected area of the alert message
@type	1	string	A national-assigned string designating the domain of the code (e.g. FIPS in US or "SGC" in Canada…)
AEAtext	1..N	string	Contains the specific text of the emergency notification
@lang	1	language	The code denoting the language of the respective element of the alert text
LiveMedia	0..1		
@bsid	1	unsignedShort	Identifier of the Broadcast Stream contains the emergency-related live A/V service.
@serviceId	1	unsignedShort	Integer number that identifies the emergency-related A/V Service.
ServiceName	0..N	string	A user-friendly name for the service where the LiveMedia is available
@lang	1	string	The language of the text described in the ServiceName element
Media	0..N		Contains the component parts of the multimedia resource.
@lang	0..1	language	The code denoting the language of the respective element **Media**
@mediaDesc	0..1	string	Text describing the type and content of the media file
@url	1	anyURI	The identifier of the media file
@contentType	0..1	string	MIME-Type of media content referenced by `Media@url`
@contentLength	0..1	unsignedLong	Size in bytes of media content referenced by `Media@url`

LOCATION - WASHINGTON, D.C.



DEVELOPING STORY

CSX TRAIN DERAILMENT

Shelter in place order for Brentwood, Trinidad, Noma, Eckington and Capitol Hill.
Remain indoors. Close all windows and doors.

AWARN

<< HAZMAT ALERT >> | AMMONIA GAS LEAK

HAZMAT LOCATION & PLUME

SHELTER IN PLACE

SYMPTOMS & FIRST AID

HOSPITAL LOCATIONS & WAIT TIMES

CONTACT & MORE INFO

ATSC 3.0 Security

System-wide security is a critical function today for any Internet-connected device

- A TV set that can be hacked? Yes!

Content protection for high-value programs is very important

- Digital Rights Management (DRM) is an essential requirement for content providers

Security enables new business models for ATSC 3.0

- Subscription services
- Monthly fee for access to the service
- “Freemium” (i.e., user registers and then content is free)

Subscription options for alternate components

- Custom views; e.g., pay for “dashboard cam” video in an auto racing event
- Pay-per-view programs
- HD free-to-air, UHD subscription service

Security Results

Content Encryption (CA and/or DRM)

- Allows charging for premium content
- Allows use of “Freemium” model
  - For example, agreement to allow anonymous usage monitoring in return for access to extra/premium content
- Allows protection of content once it arrives on receiving device

Allows transactions over the Internet

- Return channel has same concerns as general Internet use, but same technology solutions can be used

Provides protections against MITM attacks

- Application & Signaling Signing
- Use of DRM on content & signed signaling

ATSC 3.0 is a Powerful New Tool

- New business opportunities
- Flexible physical layer supports wide range of service types
- Great improvements in pictures and sound
- New interactivity features
- Advanced emergency messaging tools
- New accessibility enhancements
- More robust signal and higher data capacity
- And, and, and….

ATSC 3.0 Standards

Suite of Standards

- A/300:2017, “ATSC 3.0 System”
- A/321:2016, “System Discovery and Signaling”
- A/322:2017, “Physical Layer Protocol”
- A/324:2018, “Scheduler / Studio to Transmitter Link”
- A/330:2016, “Link-Layer Protocol”
- A/331:2017, “Signaling, Delivery, Synchronization, and Error Protection”
- A/332:2017, “Service Announcement”
- A/333:2017, “Service Usage Reporting”
- A/334:2016, “Audio Watermark Emission”

- A/335:2016 “Video Watermark Emission”
- A/336:2018, “Content Recovery in Redistribution Scenarios”
- A/337:2018, “Application Signaling”
- A/338:2017, “Companion Device”
- A/341:2018, “Video – HEVC”
- A/342 Parts 1-3:2017, “Audio”
- A/343:2017, “Captions and Subtitles”
- A/344:2017, “ATSC 3.0 Interactive Content”
- A/360:2018, “ATSC 3.0 Security and Service Protection”

Catching a tiger by the tail (make sure you hold on)

In the past, television technologies were stable for long periods of time

Now, technology is changing at an exponentially increasing rate

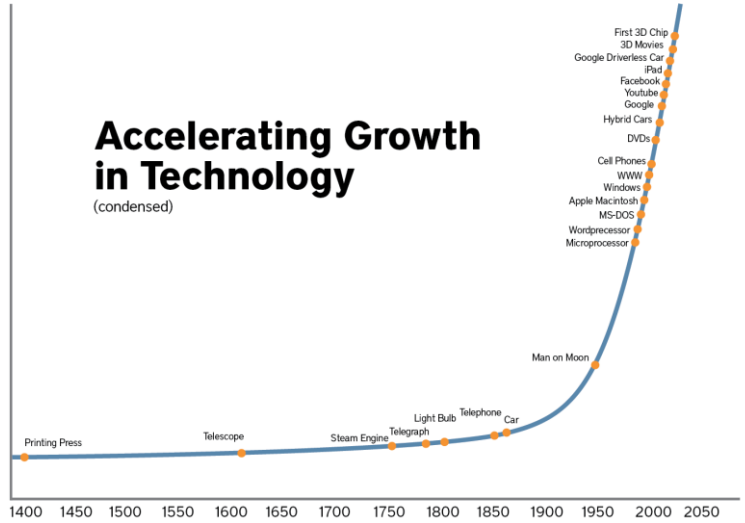
- NTSC → ATSC 1.0 → ATSC 3.0

For ATSC 3.0

- Recognition that graceful evolution of technology is now required
- A desire to become part of the internet & use its tech (the tiger)

Approach

- Major/Minor versioning & signaling for technologies
- Ability to signal capabilities required to “render” content
- Use of W3C technologies & mechanisms to keep current



Questions?

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