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Sinclair's 3.0 Vision - The Future of Broadcasting

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Abstract Submitted

What a fast-paced last few years for us Broadcasters. Spectrum is in demand, and the other wireless guys (wireless carriers…) claim they need what we have. Reverse auction, Forward auction, back and forth like an exciting ping-pong match (is there such a thing?), Table of Allocations, Repack, 39-months. Sound familiar? Well, forget it!

Soon the only important questions will be, "what are we doing and when can we start broadcasting with Next Gen?"

This discussion will bring to the audience an understanding as to how we will wield the new tools and assumptions that shape Quality of Service realities for Next Gen Broadcasting, unlocking the unique resources we offer. We must turn our wildly outdated theoretical coverage contours into “areas of services” with single frequency network deployments grounded in real world interference boundaries, and understand the impact this will have on our business assumptions and new opportunities. **What does the Broadcast network of the future look like?** Sinclair, ONE Media and others are turning from contemplation to consummation.

The intent is to engage the audience in challenging the long-held assumptions of "what is Television Broadcasting?" and provide new insight into the unique opportunities to establish relevance in today's rapidly converging digital IP world with "BaaS (Broadcast as a Service), positioning and developing Broadcasting's central role in the emerging 5G world.

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INTRODUCTION

This paper presents the main elements and continuation of a vision for terrestrial broadcasting (Ch. 2-36) in the United States with a "Next Generation" standard (on a voluntary basis) after the FCC Incentive Auction concludes in 2017. The culmination of the Auction requires a repack of those stations transmitting on the 14 channels sold to the wireless carriers (Ch. 38-51) into the space occupied currently by other broadcasters (Ch. 14-36), squeezing them together with as little interference as possible. The timing provides a unique opportunity to align the repack with the voluntary adoption of the newly minted ATSC 3.0 broadcast standard.[1] The vision builds on the ATSC 3.0 standard and creates an understanding of how to deploy a Next Generation Broadcast Platform (NGBP) aligned towards the Internet and emerging 5G system architectures.

Sinclair Broadcast Group and its affiliate, ONE Media, have been founding participants and contributors to the ATSC 3.0 standard-setting process since before it began with the original 1.0 standard. These two companies have been immersed in the research for a "Mobile First" opportunity that prepares the broadcast industry for entry into entirely new lines of business, beginning with government approval of the new standard expected later this year. Those new business opportunities may be in concert with or, in some cases, competitive to other wireless carriers (Verizon, AT&T, et al). But the competitive spur sought by consumers and the government will be enhanced by the introduction of the new standard and capabilities offered to broadcasters who have been trapped on a platform ill-suited to connect in the mobile/IP world today with all devices and through the Internet.

The significance of the IP-based enhancement of ATSC 3.0 in the U.S. needs to be viewed in concert with changes to international specifications for mobile communications. The 3rd Generation Partnership Project (3GPP), a collaborative group of several telecom technical groups across the world

[1] Advanced Television Systems Committee http://atsc.org/standards/atsc-3-0-standards/

aimed at developing global specifications for mobile systems, has recently published a 5G service requirements document, TS 22.261.[2] It includes future innovation in broadcasting, and the 5G requirements include a new radio (NR) with a 100% broadcast-only mode and larger tower (cell) spacing up to 200km. The wireless carrier industry, when "armed" with 600 and 700MHz spectrum (a result of reallocation of broadcast channels in the FCC Incentive Auction), large tall tower deployment opportunities and a supportive standard could well be real competitors to Broadcasters. Ironically, the incentive auction fundamentally resulted in a reallocation of channels from broadcasters to wireless carriers that will be used by those carriers essentially for broadcast-like service. This 5G activity in the 3GPP organization also requires a new system architecture based upon software defined networks and network function virtualization (SDN/NFV) and the concept of "Network Slicing." As the Next Gen ATSC 3.0 standard is deployed, broadcasters then can provide many of the service offerings previously limited to wireless carriers. This convergence of players and platforms offering services to all users marks both a competitive spur to all players and cooperative opportunities by merging the platform capabilities, focusing on what each party does best. The convergence relies on broadcasters' one-to-many architecture and high capacity data distribution capabilities enabled by ATSC 3.0 combined with the one-to-one service offerings of wireless carriers.

From a high-level perspective, the Sinclair vision includes many technical and architectural similarities to 5G. This paper posits new use cases and a call for action, stating that the time is ***now*** to deploy a new broadcast system architecture supporting single frequency networks (SFN) and using the cloud to enable broadcast innovation in the U.S. In order for the original wireless broadcast system (TV) to remain relevant and competitive in the future, broadcasters must embrace a new broadcast system architecture with the introduction of ATSC 3.0.

Sinclair's vision is to develop a Next Generation Broadcast Platform (NGBP) relying on the flexibilities built in to the ATSC 3.0 standard as a foundation to revolutionize and re-invent the world of broadcasting. Broadcasters have the ability to deliver data through a large, flexible, virtual, broadcast bit-pipe, supporting diverse services beyond fixed in-the-home television including providing the backbone of the Internet of Things, true, robust mobile and portable reception, and app-based services under a HTML5 run time environment. Transporting data using high efficiency video coding in an all-IP network is facilitated by the ISO/MMT 23008-1 MMT standard[3] that can be used to enable hybrid broadcast/broadband services. Additionally, the "Bootstrap" portion of the ATSC 3.0 standard (A/321)[4] will be explored in new ways to allow for future growth in data provisioning. The spirit of the bootstrap, as stated in the standard introduction section 1.1,[5] will be a synergistic component of the flexible architecture enabling many new use cases. Broadcasters will no longer be bound to delivering "plain old

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[2] http://www.3gpp.org/news-events/3gpp-news/1831-sa1_5g

[3] ISO/IEC 23008-1:2014 MPEG Media Transport (MMT) technologies, https://www.iso.org/standard/62835.html

[4] http://atsc.org/standards/atsc-3-0-standards/

[5] A/321, http://atsc.org/wp-content/uploads/2016/03/A321-2016-System-Discovery-and-Signaling-1.pdf

> "This comparatively short signal precedes, in time, a longer transmitted signal that carries some form of data. New signal types, at least some of which have likely not yet even been conceived, could also be provided by a broadcaster and identified within a transmitted waveform through the use of a bootstrap signal associated with each particular time-multiplexed signal. Some future signal types indicated by a particular bootstrap signal may even be outside the scope of the ATSC."

television." While continuing to deliver the most robust and technically spectacular TV programming, they will be freed to roam the world of "Data" writ large.

THE FOUNDATION OF THE VISION

The Next Gen standard setting process began only 3½ years ago. Sinclair provided one of 10 proposals from 19 organizations that responded to the ATSC 3.0 "Request for Proposals" for a non-backwardly compatible physical layer in August, 2013,[6] after which the ATSC began the 'Physical Layer' Technical Proposals Evaluation Process.[7] Although no single proposal submitted was selected in whole, Sinclair and its ONE Media affiliate created and organized industry support for the critical physical layer of the ATSC 3.0 standard. Concentrating on improving flexibility in a new standard, the central idea was to enable a "Mobile-First" strategy and one that integrated broadcasting in the IP delivery stream. Sinclair's principal pursuit was ensuring that the developed standard provided for an ability to evolve. This critical element has become an essential feature of the new standard.

The new ATSC 3.0 technology itself is the indispensable prerequisite for an economically viable future within the broadcast television industry. Sinclair understands, however, that, in addition to the ATSC 3.0 technology, a new broadcast system *architecture and infrastructure*, aligned with the Internet and emerging 5G networks, is absolutely essential to enable both innovation and competition in the broadcast market.

Broadcasters have transitioned from an analog to a digital transmission standard, but the legacy broadcast terrestrial system architecture that has existed for more than 60 years remains unchanged as we contemplate deployment of ATSC 3.0. The studios, transmitter links, and transmitters operated by broadcasters today continue to be wedded to a static infrastructure incapable of rapid change, in stark contrast to the dynamic nature of other technological platforms capable of evolving to meet new customer needs. Sinclair's research confirms that this legacy architecture now poses a serious impediment to the vision of broadcasters using their licensed spectrum in a future, competitive bit-distribution market (without regard to the nature of the bits). A new, innovative, holistic system architecture for a broadcast data transmission platform enabled by ATSC 3.0 will be deployed to replace this antiquated system.

Although the ATSC 3.0 standard is IP-based, to leverage new business opportunities fully, a new system architecture must be created. Today's consumer expectations are driven by continuous innovation in services and choice of providers offered in a competitive landscape. This will continue to expand engagement with the Internet (wired and wireless) and ever-expanding cloud based services, and will drive the nature of converged hybrid solutions in the future 5G world ahead.

THE ORGANIZED NATURE OF OUR WIRELESS COMPETITION

The original "wireless service" delivering data to consumers is broadcasting. Its one-to-many architecture has been the backbone of content delivery for 90 years. The "wireless" term, however, has been appropriated by those companies providing two-way service with a one-to-one relationship to users. With the technological developments inherent in the Next Gen, ATSC 3.0 standard, Broadcasters will have the ability to expand their data delivery capabilities to much more than television programming and use

[6] Physical Layer ATSC 3.0 Proposal Submissions, http://atsc.org/newsletter/physical-layer-atsc-3-0-proposal-submissions/

[7] http://atsc.org/newsletter/detailed-atsc-3-0-physical-layer-technical-proposals-being-evaluated/

the enormous data "pipe" to offer services to customers that have been tied by technology to platforms that offer only a one-to-one relationship. There are innumerable data transmission use cases that do not require this one-to-one and two-way feature. In the non-television data delivery world, however, broadcasters are new players confronting sophisticated and well-entrenched operators. Broadcasters' competitors in this data delivery world are the 'other' wireless industry players. They are entrenched, well organized, well-funded, and have mapped out a long-term strategy to dominate the data distribution market. Broadcasters armed with ATSC 3.0 pose a significant market disruption to them, but may also provide a complementary service as those entrenched carriers move to maximize their services in the most efficient way possible. Including broadcast delivery in their plans may be an entirely logical enhancement in the delivery paradigm.

One of the wireless industry's many forums for innovation, the Next Generation Mobile networks (NGMN) alliance[8], issued a 5G whitepaper in March, 2015.[9] This whitepaper is premised on the realization that new technology and a new system architecture will be required for wireless carriers to be competitive with the web-scale IT players including Google, Facebook, Amazon, Microsoft, *etc*. The proven IT networking paradigms (web-scale IT players) of 'Software defined networking' (SDN) and 'network function virtualization' (NFV) was ripe for rapid innovation and represents a major disruption in the wireless industry as its participants head toward adoption of 5G related strategies. It is clear that the wireless and IT industry players are converging toward use of 5G distribution. Broadcasters can also play a significant role in that deployment.

The Sinclair vision contemplates a next generation platform using SDN/NFV that enables sharing[10] and an intelligent programmable 'Broadcast Cloud.' This is a virtualized architecture which uses pooled and licensed broadcast spectrum (VHF/UHF channels 2-36) and infrastructure to create a multi-tenant abstracted, virtualized cloud that starts at the broadcast antenna and extends backwards into the network. This platform is managed by a neutral host entity, enabling the flexibility to provide for innovation within the broadcast industry participants, and can be termed Broadcast as a Service (BaaS). The Neutral Host model is well known and gaining prominence for deploying wireless services. The Neutral Host model can reduce mobile operator costs, speed time-to-market for a multi-operator service, and offload the responsibility for maintaining infrastructure from a carrier to a third party and deemed useful for future 5G [11] services.

The notion of a virtualized system architecture is new to the broadcast industry. To have its place in the "system must have" category, it must be more economic to deploy and operate than a traditional architecture while delivering diverse services and new business models that meet consumer expectations and evolve easily in the future. The resulting platform also guarantees that each tenant (broadcaster) remains totally isolated and in control of its own services, running independently within the architecture.

[8] Next Generation Mobile Networks, https://www.ngmn.org/home.html

[9] NGMN - 5G White Paper, https://www.ngmn.org/5g-white-paper.html. This White Paper serves as guidance in 3GPP for 5G standard development

[10] FCC permits broadcaster sharing agreements inside / outside incentive auction. The spectrum management function in BMX as part of Sinclair's vision of BaaS for licensed spectrum sharing is analogous to SAS function used in FCC authorized CBRS 3.5 GHz band https://apps.fcc.gov/edocs_public/attachmatch/DA-16-1426A1.pdf

[11] ATIS provides some guidance, https://www.atis.org/5G2016/presentations/5gEmergingCoreTechnologies.pdf

The individual broadcast tenants may have customized services which are composed of IP flows (content, data) orchestrated in virtualized IP core and radio access (regional cloud) serving a city/market/region.

This 'chaining of services' is termed "Network Slicing"[12] in the world of 5G. Network Slicing in 5G is central to the vision of many countries: the future Europe[13], Japan[14], and the U.S.[15] are all based on the original vision of the referenced NGMN 5G White Paper. The technology that provides for Network Slicing is also essential to NGBP BaaS. The planning document that Verizon published in February 2016, (5G system reference architecture using SDN/NFV,[16]) provides insight into the kinds of use cases being made possible with this approach.

The Impact on Broadcasting

We have focused, for the sake of simplicity, primarily on the broadcast domain of the envisioned hybrid services as a first step. The NGBP is expected to enable new and disruptive business models for broadcasters at regional as well as national levels using single frequency networks (SFN) with targeted delivery of services using various techniques including ATSC 3.0 Layer Division Multiplexing (LDM). Most significantly the focus is on a community cloud architecture model that enables a new market-based paradigm in broadcast sharing, Broadcast-as-a-Service or BaaS.

The ATSC 3.0 standard offers broadcasters wide operating points as shown in Figure 1, below, compared to the legacy ATSC 1.0 single operating point referenced. The blue line is the Shannon limit[17] as defined by classical information theory which states that a code/modulation scheme should exist to approach the limit. The low-density parity-check (LDPC) forward error correction (FEC) codes and quadrature amplitude modulation (QAM) constellations in ATSC 3.0 have been optimized and are very close to this theoretic Shannon limit, which is good news. The ATSC committee reviewing this piece of the standard, however, being contribution driven, focused on the higher capacity/less robust range of possibilities in Figure 1 for services such as fixed ultra-high definition television (UHDTV) driven by conventional 'broadcast television' requirements such as those in South Korea with its planned launch of UHDTV service in early 2017.

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12 FierceWireless, http://www.fiercewireless.com/tech/network-slicing-to-play-big-role-5g-report

13 The 5G Infrastructure Public Private Partnership (5G PPP), https://5g-ppp.eu/white-papers/

14 Fifth Generation Mobile Communication Promotion Forum (5GMF), http://5gmf.jp/en/

15 5G Americas, http://www.5gamericas.org/files/6814/8718/2308/3GPP_Rel_13_15_Final_to_Upload_2.14.17_AB.pdf

16 Verizon Network Infrastructure Planning, http://innovation.verizon.com/content/dam/vic/PDF/Verizon_SDN-NFV_Reference_Architecture.pdf

17 A Mathematical Theory of Communication, By C. E. SHANNON, http://web.mit.edu/persci/classes/papers/Shannon48.pdf

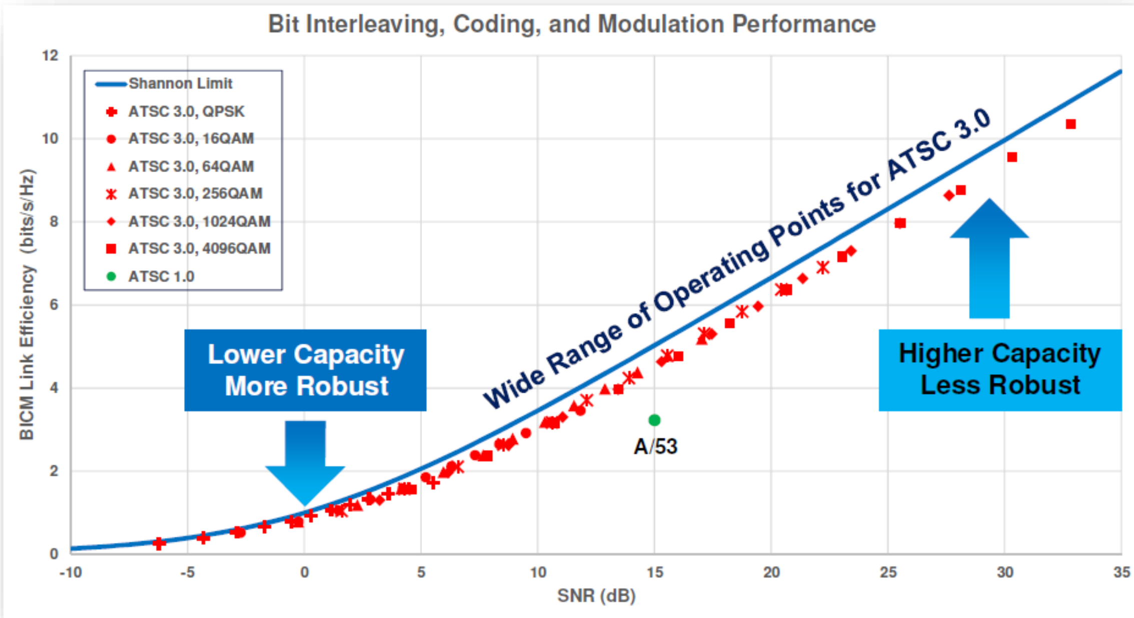

Figure 1 ATSC 3.0 Spectrum Efficiency bps/Hz vs. SNR (dB)

Although the envisioned NGBP architecture will address all the operating ranges, special attention will be given to battery powered devices as part of the "Mobile First" strategy. These devices have operating points which are more towards the lower capacity/more robust ranges of Figure 1. As well, there will be a concentration on device categories that have to conserve battery while still receiving emergency notification, *etc*. There is a need for research that may be concentrated on VHF services to find solutions help to mitigate the physics of known higher impulse noise environment. The NGBP architecture will cover all of the broadcast channels 2-36 in the United States after conclusion of the Incentive Auction. Although spectrum may not be fungible because of the attributes of each channel, an intelligent network combined with new technical tools will permit the market to solutions for all channels VHF/UHF 2-36 given a lighter regulatory touch with pooled broadcast resources.

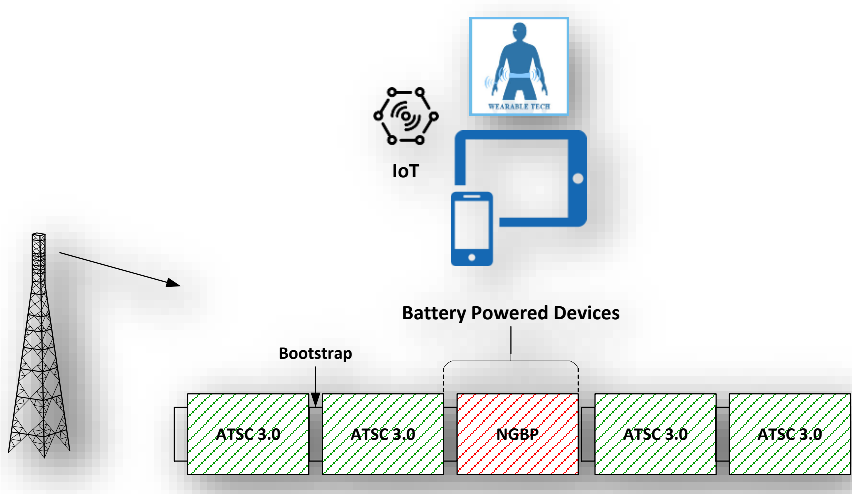

Figure 2 A/321 usage to enable TDM of Diverse Waveforms NGBP architecture

Figure 2 shows the A/321 bootstrap used to time multiplex ATSC 3.0 and NGBP (RF frames) each preceded with a universal bootstrap. The frames contain different waveforms optimized for a category of devices such as battery constrained, IoT, *etc*. The notion that one waveform type serves all service types has been proven to be both inefficient and unwise, and research to enable many waveforms for many differing services exists for 5G in the future. This reality will exist for new broadcast paradigms as well, and will have to be addressable within the overall architecture deployed. The concept of a Centralized Radio Access Network (C-RAN) architecture, which was published in a whitepaper by China Mobile in 2011[18] as a concept, can now be adapted to broadcast for the first time in the NGBP architecture. The SDN/NFV cloud architecture described in this document leverages virtualization starting from the broadcast antenna by abstraction using C-RAN and then Network Slicing in IP Core and RAN in the cloud on a service by service basis to ensure broadcast innovation in the U.S.

Sinclair considers the real opportunity presented to broadcast licensees, armed with a new ATSC 3.0 standard (designed to be non-backward compatible with the current ATSC 1.0 and forward compatible with IP networks), to be the development of a new system architecture for broadcast in the 21st century. This can act as a catalyst to align broadcast with the Internet and emerging 5G networks, and can address convergence holistically at both the application and infrastructure layers in an IP world. This can be done while also ensuring maximum flexibility, elasticity and extensibility only possible in an environment operating in software using proven IT technology of the web-scale players.

That being said, the timing could not be better because the wireless industry today is also considering and beginning to deploy pieces of a new wireless system architecture using IT cloud technology (SDN/NFV) to meet the diverse requirements of future 5G services. However, this will be an evolution of LTE towards 5G and is constrained by maintaining the legacy and therefore will be a "brownfield" approach over many years, embracing existing complexity, and accelerating the overall solution engineering process reliably, including enabling phased, incremental change wherever possible.

NGBP "Virtualized" Architecture

The deployment window of the NGBP architecture discussed here contemplates a "greenfield" approach to a new broadcast system architecture without concern for legacy equipment or protocols. Given that 'one-way' broadcast has much lower technical complexity (relative to LTE/5G) due to the physics of broadcasting, we see opportunity to re-invent broadcasting in a 21st century fashion fully realizing a new (but lower) level of investment is required than if being deployed 'from scratch' by wireless carriers.

In the basic introduction to cloud computing that we are highlighting in this presentation, Figure 3 (below) shows the basic NFV architecture model defined by ETSI NFV ISG[19] at a high level which forms the basis of various cloud nodes in the NGBP architecture under discussion.

[18] http://labs.chinamobile.com/cran/wp-content/uploads/CRAN_white_paper_v2_5_EN.pdf

[19] ETSI, Network Functions Virtualization http://www.etsi.org/technologies-clusters/technologies/nfv

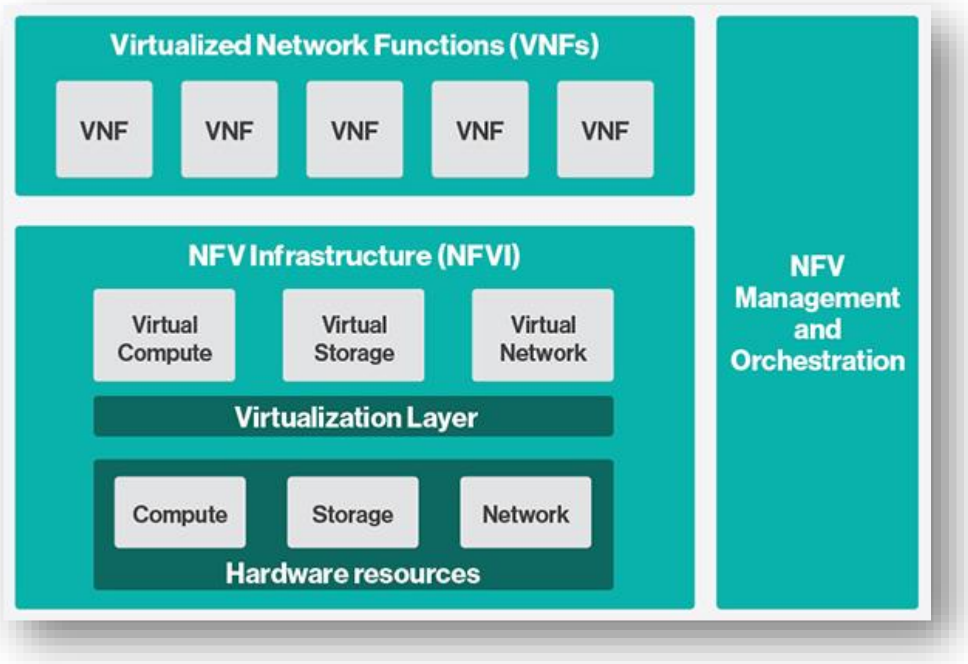

Figure 3 Basic ETSI NFV Model for Cloud Computing

There are three basic entities shown:

- NFV Infrastructure (NFVI) made of off-the-shelf computers (Servers), Storage and Networking. Abstraction is provided by a Hypervisor (Virtualization Layer) such as VMware. Above the virtualization layer is the virtual computer, storage and networking. The NFVI is orchestrated by an Open cloud management system such as OpenStack.
- The VNFs above NFVI are the virtual functions running on the virtual machines and these VNF represent functions that normally run in hardware appliances but are being instantiated in software. This could be firewall router in IP core network or ATSC 3.0 physical layer functions in Radio Access network (RAN) to be shown.
- The Management and Orchestration (MANO) provides overall orchestration and management via entities Virtual Infrastructure Manager (VIM), Virtual network Function Manager (VNFM), Virtual Network Function Orchestrator (VNFO) the details of which will not be discussed. However, the wireless industry is now seriously embracing open source software in 2017[20] and this harmonization will be good timing for NGBP and broadcast.

[20] http://www.rcrwireless.com/20170223/telecom-software/linux-foundation-combines-open-source-ecomp-open-o-into-onap-tag2

Figure 4 is a general drawing representative of the Regional and Central Clouds in NGBP which use open source software such as OpenStack for VIM. The NGBP "BaaS" model under discussion can be considered a distributed "community cloud" model.[21]

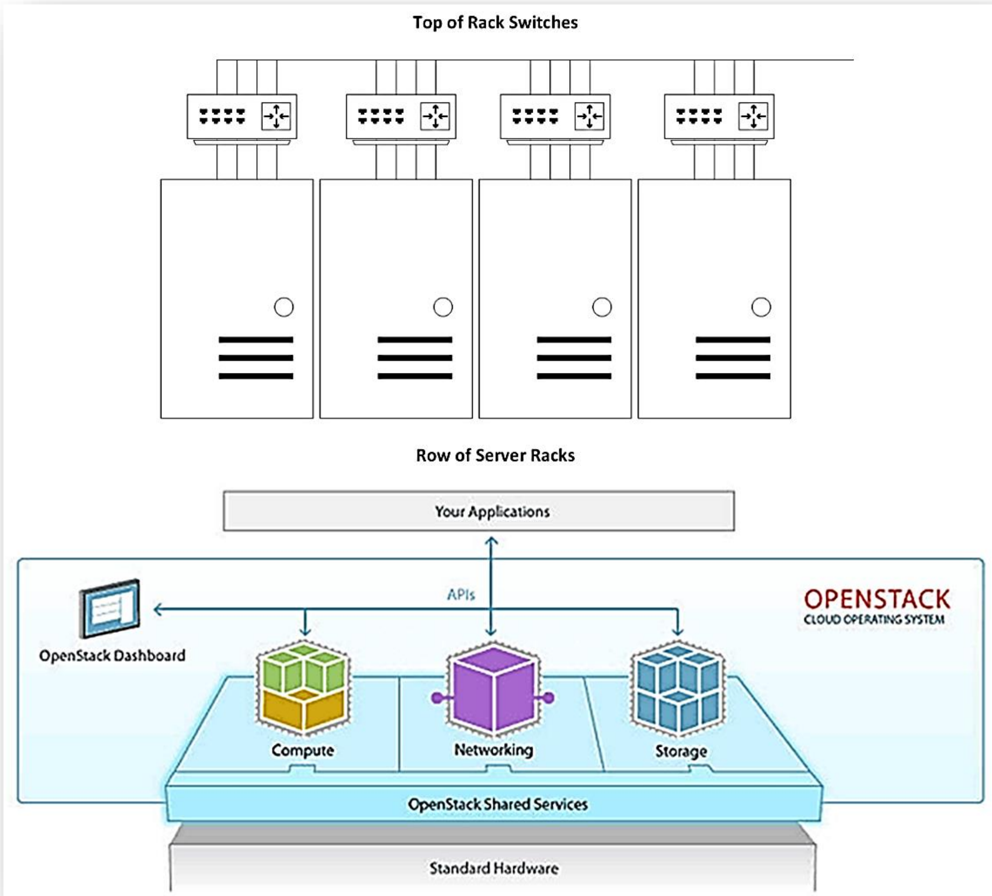

Figure 4 Basic Regional / Central Cloud NGBP

Figure 5 (below) shows a high level view of the new broadcast system architecture representing the Sinclair vision of a NGBP where there are six major 'high-level' entities:

- Regional Data-Centers (IP Flows /Baseband Waveforms)
- Remote Radio Heads (RRH)
- Broadcast Market Exchange (BMX) Cloud w/BSS
- Central Private Cloud (w/OSS)
- Network Operations Center (NOC)
- BaaS Tenant Dash Board

[21] 4 Types of Cloud Computing Deployment Model You Need to Know - Internet and Technology Blog - Internet and Technology

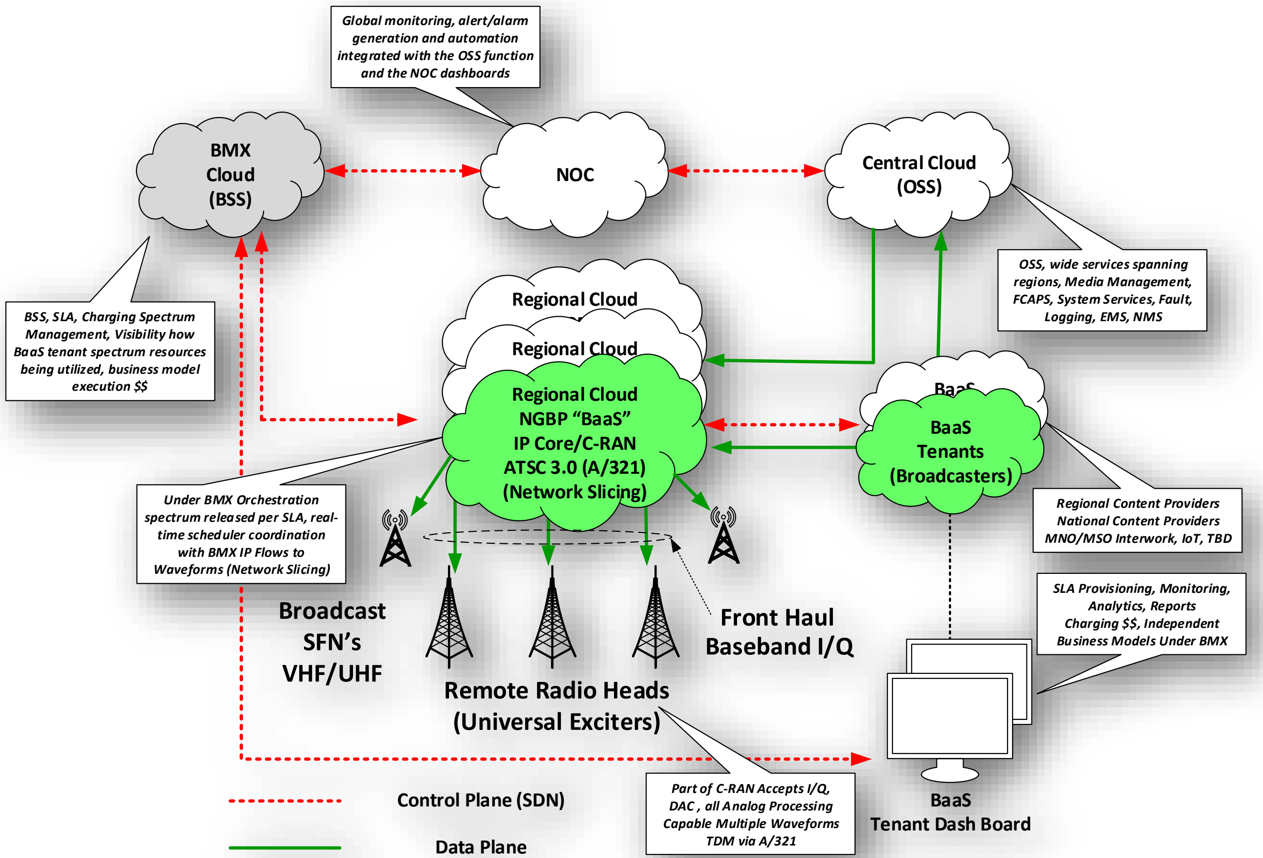

Figure 5 Simplified High level view NGBP Architecture (Community Cloud Model)

This is a new paradigm for broadcast but the concepts of Neutral Host[22] solutions have been deployed in the wireless industry for years and are now the basis of emerging 5G architectures. The NGBP BaaS spirit is to leverage existing protocols and interfaces and create new ones only when required and by modifying to align with the constraints[23] of broadcast physics.

Figure 5 (above) is also high level conceptual view of the vision of a nationwide architecture of NGBP “BaaS” that can be used as a reference to introduce basic concepts under discussion. Each BaaS participating licensed broadcaster is pooling resources under BMX[24] in a market/ region of country uses the services of a regional cloud[25] under control of business / spectrum management in the entity BMX

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[22] https://sites.atis.org/insights/atis-neutral-host-solution-better-wireless-coverage-public-spaces/
[23] The one-way nature of broadcast protocols is a major advantage when compared to unicast complexity as in 5G
[24] The BMX (Broadcast Market Exchange) concept was first introduced in Sinclair’s ATSC 3.0 proposal Sept 2013. It includes options for virtualized spectrum sharing by two or more licensed broadcasters using a business management entity termed a Broadcast Market Exchange (BMX).
[25] Network Function Virtualization (NFV), Software Defined Networking (SDN), Network Slicing, COTS hardware, Type 1 Hypervisor and Open Source Software such as OpenStack, Open Daylight, etc.

which only has the control plane (non-real-time data services) and could be instantiated in AWS cloud or equivalent.

The red lines indicate the control plane (SDN) and the green lines indicate the user data plane in this community cloud model. For perspective, all the BaaS licensed broadcast tenants in a local market/DMA are located inside the (Green) cloud shown on right side of drawing. These local broadcast partners or tenants of the community cloud would send IP data flows (under BMX control) into a regional data center (SDN/NFV) shown and software network functions (NF) in IP core are assigned or chained together and then software network functions (NF) in the RAN are also to construct specific digital waveforms. This linking of functions is termed "Network Slicing"[26] in 5G and will be adopted in NGBP. The I/Q digital baseband signal is then transported to the broadcast universal exciter (RRH) at the transmitter sites in a SFN on a given channel (2-36) using concepts of broadcast C-RAN.

Another example in Figure 5 is concept of a National Content Provider tenant that would send IP data flows (under BMX control) to the central cloud where these are processed and then routed to the regional cloud/s per the use case defined by SLA running in the BMX. Also, two or more broadcast tenants in adjacent markets could coordinate (business deal) through a central cloud to cover larger geographic regions such as the northeast corridor of the U.S. for mobile services to vehicles managed by the Broadcast Market Exchange (BMX) under a business subscriber license agreement (SLA).

In the future, the NGBP "BaaS" architecture (as with 5G architecture) will be using network slices that are dynamic and are 'spun up' (initialized), the life cycles managed, and then killed quickly to monetize spectrum dynamically. This enables potential for diverse services under BMX which allows spectrum to be used efficiently and to serve the public interest better, (see Rivada Networks "Dynamic Spectrum Arbitrage" [27]). The normal time consuming process of specifying, standardizing and then implementing is too slow to be competitive in the future with the web-scale IT players and use of open source software under SDN/NFV in a competitive market. This is why a new broadcast architecture is so important as ATSC 3.0 is emerging. It can serve as a foundation in a very competitive market in the future. Broadcast has it place in 21st century being mobile-first and bringing forward the best economic solution that can potentially converge in IP world.[28]

Figure 5 also reflects how players will utilize the platform to provide video and other real-time broadcast services, designed to be managed and orchestrated in an automated fashion in this complex telecommunications architecture. Included among these are the Regional Clouds (IP Flows /Baseband Waveforms) of Figure 6 (below).

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[26] http://www.4gamericas.org/files/1414/8052/9095/5G_Americas_Network_Slicing_11.21_Final.pdf
[27] http://finance.yahoo.com/news/rivada-networks-adds-patent-portfolio-194100604.html
[28] http://img.lightreading.com/downloads/Shared-Spectrum-for-5G-New-Radio.pdf

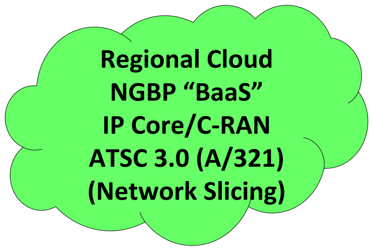

Figure 6 NGBP "BaaS" Regional Cloud

These entities can provide potential virtualized functions including:[29]

- ATSC 3.0 Base-band processing
  - This is at the heart of the broadcast C-RAN architecture, where the base-band processing is centrally done for numerous RRHs and tenants using pooled resources
- ATSC 3.0 PHY layer processing
  - This takes care of creating the physical layer frames (Multi-RAT) to be sent over the air interface using various techniques and leveraging the flexibilities of ATSC 3.0
- MAC Scheduling
  - This determines the best way to pack the bits into the physical OFDM frames and coordinates with spectrum management system in BMX to have pooled spectrum resources released to Mac Scheduler to perform these real-time scheduling functions
- Network Slicing
  - Virtualized resources (VNFs) linked together to instantiate services like in 5G
- Network Management
  - This function ensures robustness against network overload, protection against denial of service attacks, intrusion detection, firewall functions, *etc*.
- Charging Data Record (CDR) generation and management
  - Manages any charge data needed to facilitate the business relationships
- System services
  - Timing and Frequency Synchronization and distribution management
  - Logging/KPI/diagnostics generation and management framework
  - Fault and Failure management

[29] Note: The NGBP platform and Regional Data-Centers will use IEEE 1588 (PTP) to establish frequency, phase and time for operation and will fully support ISO/IEC 23008-1 MPEG Media Transport (MMT) for Media Sync and Timed services. Including hybrid broadcast / broadband and for establishing Single Frequency Networks. The regional cloud will provide ATSC Time (ATSC 3.0) to RRH to emit OTA time signal to establish wall clock (NTP, *etc*.) at the terrestrial receiver. The details of this hybrid synchronous timing model are well understood by Sinclair but will not be discussed in this vision paper.

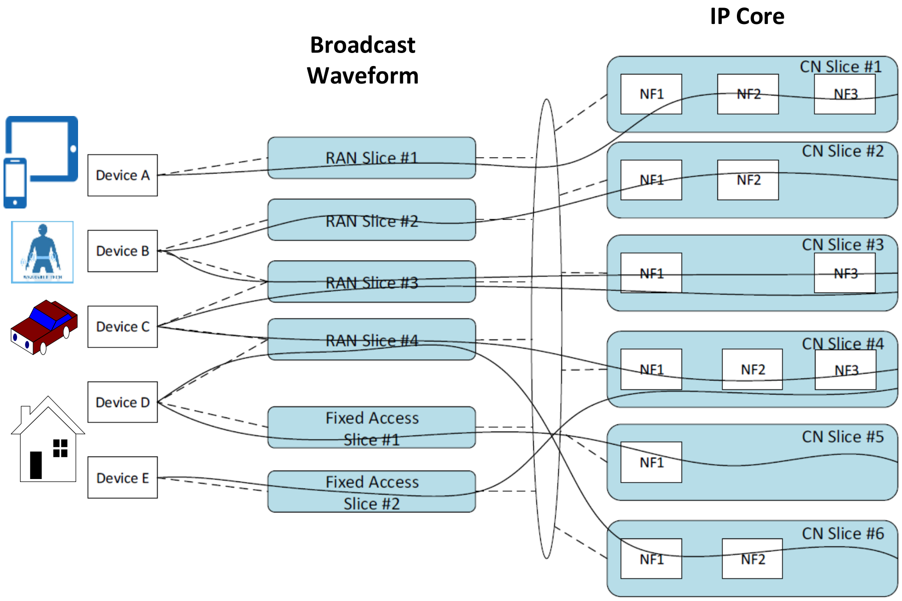

Figure 7 High Level Concept Network Slicing in NGBP

The network slices (Figure 7 above) are programmatic and use the service level agreements (SLA) enforced in BMX and are targeted to deliver tenants diverse use cases as a broadcast service (BaaS). The abstraction by C-RAN allows for the remote radio heads (RRH) to be agnostic to specific types of waveforms being conveyed via I/Q transport, carrying suitable signaling. The RRH is also termed a universal exciter in NGBP. The A/321 bootstrap is synergistic with this architecture as shown in Figure 2 and allows creation and customization of multiple broadcast waveforms, termed Multi-RAT[30] in the wireless industry, to enable market driven competition and evolution of broadcast services in future.

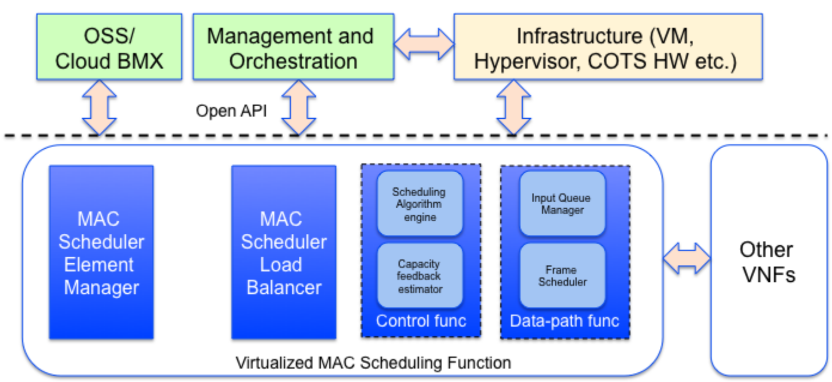

Figure 8 Concept Interfaces MAC Scheduling Function (VNF) Regional Data Center

Figure 8 shows a simple concept of a single, one-of-many VNFs, in the regional cloud - the MAC Scheduler. this example illustrates the functional usefulness of the VNF. It is not meant to assume that the various functions enabled need to be individually understood.

30 https://www.atis.org/5G2016/presentations/5gCanItDoTheSplits.pdf

The MAC Scheduler Load Balancer works with the NFV Orchestrator to ensure elasticity and reliability. The MAC Scheduler works in real-time by coordination with BMX for scheduling of physical layer resources.

The MAC scheduler VNF would interact with other VNFs such as the Buffering and Queue Management VNF, the ATSC 3.0 ALP Processing VNF, and ATSC 3.0 physical layer VNFs, *etc*. The MAC Scheduling VNF is shown as (I) in Figure 9 below showing a partial concept of service chaining enabled by Network Slicing.

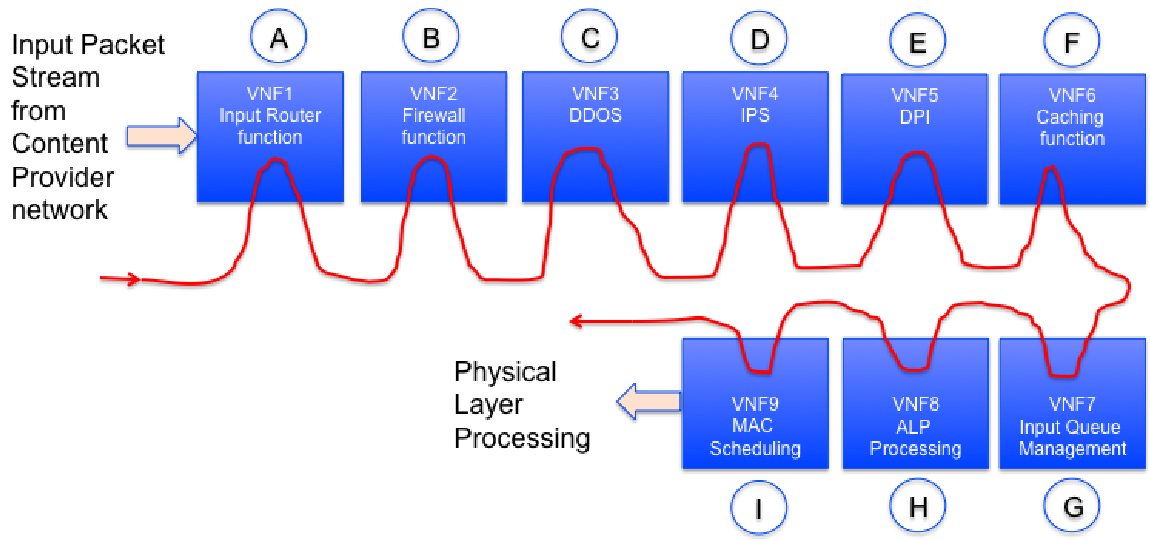

Figure 9 Concept VNF chaining to create NGBP Network Slice

Figure 9 shows conceptually some of the VNFs (A-F) in the IP Core, and (G-I) plus others not shown that are required elements of the physical layer processing in the RAN that builds the actual waveforms. The "chaining" of functions shows the concept of Network Slicing for ATSC 3.0 which could be targeted at specific use cases such as Fixed, Mobile, Battery Powered devices, IoT, *etc*. of the NGBP tenants business models.

This chaining of NFV functions represents the software provisioning on a service-by-service basis. In the NFV world, new services can be instantiated as software-only, running on commodity hardware. Because the functions and services are realized in software using virtual circuits, these connections can be constructed and deconstructed as needed. In addition, elasticity using load balancing could provide reliability as is done by web-scale players today with service chain provisioning through NFV orchestration layer such as OpenStack, *etc*.

Remote Radio Heads (RRH) at transmitter sites:

Figure 10 shows C-RAN with RRH in LTE/5G as an example.

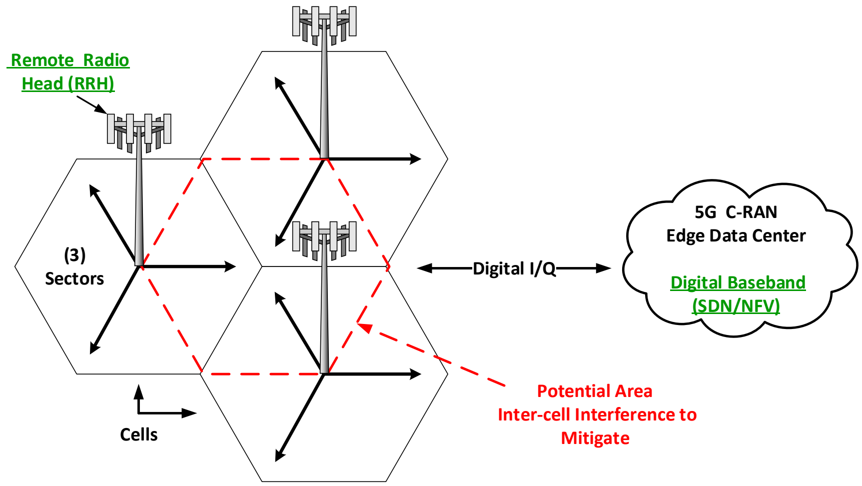

Figure 10 RRH in LTE/5G Small Dense Cells

Figure 11 shows an example of the broadcast C-RAN with RRH in NGBP.

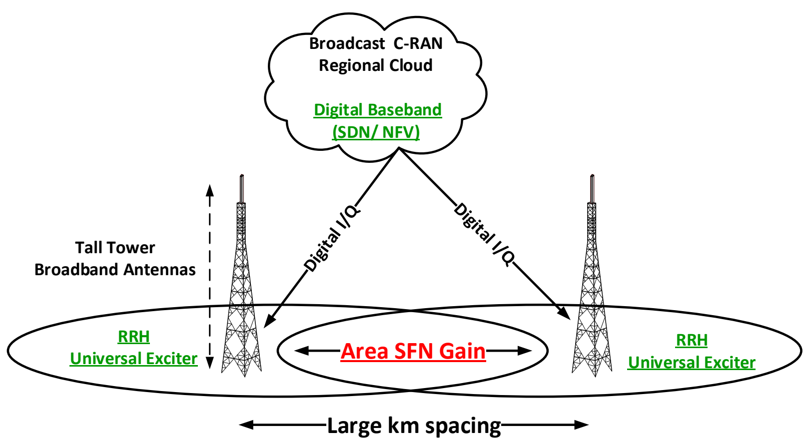

Figure 11 Broadcast C-RAN with RRH (Universal Exciters)

The broadcast RRHs are located at the SFN transmission sites and constitute a fundamental part of this broadcast C-RAN transmission architecture. In today's television broadcasting world, most licensed operators think of these as transmitter sites, islands that belong to individual entities that provide 'over-the-air' signals. In the future, the digital baseband processing (regional cloud) is connected to RRHs as I/Q[31] digital baseband samples over IP link via a front-haul network.

[31] Regardless of the exact technology approach chosen for I/Q transport, critical aspects are effective compression-decompression of the I/Q streams, as well as time and frequency synchronization over the IP front-haul network.

The broadcast RRH accepts digital baseband I/Q samples and performs DAC and all analog RF processing to generate RF waveforms (Multi-RAT) dynamically on a frame by frame basis. The signaling flexibility (A/321) supports evolution to new waveforms enabling diverse services.

Advantages of broadcast C-RAN / RRH include:

- Flexibility in Software – All digital baseband processing accomplished in regional cloud
- With centralized processing, no impact on transmitter network to evolve, Universal Exciter
- Business Flexibility can be seen synergistic with SDR (Moore's Law) future IoT, *etc*.
- Multi-carrier capability – supports ATSC 3.0 channel bonding

BROADCAST MARKET EXCHANGE (BMX) CLOUD ENTITY W/BSS

Today's broadcaster typically operates as if on an island. The new broadcast competitor or cooperative partner may not the television operator 'across the street.' Rather, wireless carriers providing OTT services can disrupt our core business but also may require our platform to enhance their service offerings. The BMX entity can be an extension of a broadcaster's new virtual IP core network. The BMX entity defines the technologies and framework to give all broadcasters an option to interoperate via an open process with defined rules and procedures for trading and/or establishing service level agreements among broadcasters now or in the future (scheduling).

The BMX can provide broadcasters with a mechanism to make optimal use of spectrum. Those can include, for example, UHF for Mobile/Portable/Nomadic services and VHF for Fixed services. BMX could provide the basis for Ad Agency "dashboard sales" on targeted basis to specific demographics or geographic regions.

The BMX should enable the following requirements for broadcasters:

- Personalized Advertising
  - Reaching the targeted audience advertisers require
  - Multiplying the value of commercial advertising
  - Providing Data Analytics to measure viewership precisely
- 'The Second Screen'
  - Interactivity, engagement, sharing and Social Networking
  - Delivered in all locations across multiple wireless connections and devices
- Robust mobile reception and deep building penetration
  - Reception in the home and on devices everywhere
  - Fixed and Mobile/Portable/Nomadic with definable QoS
- We must be engaged in this activity as 'an Industry'
  - We have to think of ourselves as more than providers of TV programming
  - As an industry, we must work together to become the leading provider of wireless data and become the consumer's champion

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Sinclair Broadcast Group has been using I/Q transport for experimental ATSC 3.0 SFN network operation in Baltimore MD / Washington DC under STA from FCC.

The BMX cloud with the business management functionality listed below can be delivered in a national cloud framework – such as AWS, *etc*.

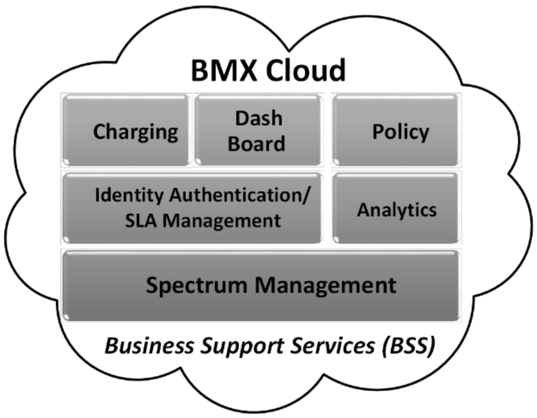

Figure 12 Some Primary Functions of BMX Cloud

Some potential Functions in support of spectrum management and business operations in BMX cloud:

- Spectrum Management Function
  - Manage a pool of spectrum resources and assign incoming media content and data service requests to available broadcasting resources. This mapping is achieved by coordination with a (real-time) resource schedulers located in the regional clouds.
  - SLA requirements have to be met in serving a service request.
  - Demographics or geography or analytics based constraint, *e.g*. certain content becomes higher priority in certain geographies, *etc*.
  - May though business agreement (SLA) allocate VHF channel (200 MHz) for better propagation and Doppler characteristics, *etc.* to serve vehicles as example of efficiently management of a dynamic pool of broadcast resources driven by market.
- Identity and Authentication management
  - role-based secure access for content providers, broadcast partners, *etc*.
- SLA Management
  - Manage the agreements between various parties – content providers, broadcast partners, broadcast network operator (neutral host), mobile network operators, *etc*.
- Policy Framework
  - Support for policies tied to SLAs that facilitate differentiated QoS for different IP data streams under different scenarios *etc*.
- Charging management
  - Management of charging related functions and facilitating business relationships
- Analytics/KPIs
  - Analytics and KPIs to track performance, help in optimize deployments, identify areas for new deployments, assist in SLA enforcement, feed into Machine-learning based Business Intelligence solutions (future) *etc*.
- Monitoring functions
  - Track operational metrics to identify/manage/predict impact to network operations, cloud services, and other aspects of the broadcasting network
- Interfaces to Regional and Central data centers
  - Manage the communications between BMX Cloud services and the various data centers

- Interfaces to NOC functionality
    - Provide support for Network Operations visibility
- System services: Logging/GUI/Dashboards/Configuration management
    - Since the system will support different partners pooling their channel resources, there is also need for tools and dashboards that partners can use for more visibility into how their spectrum resources are being consumed, related analytics, related charging information *etc*. to support their business model/s executing using BaaS

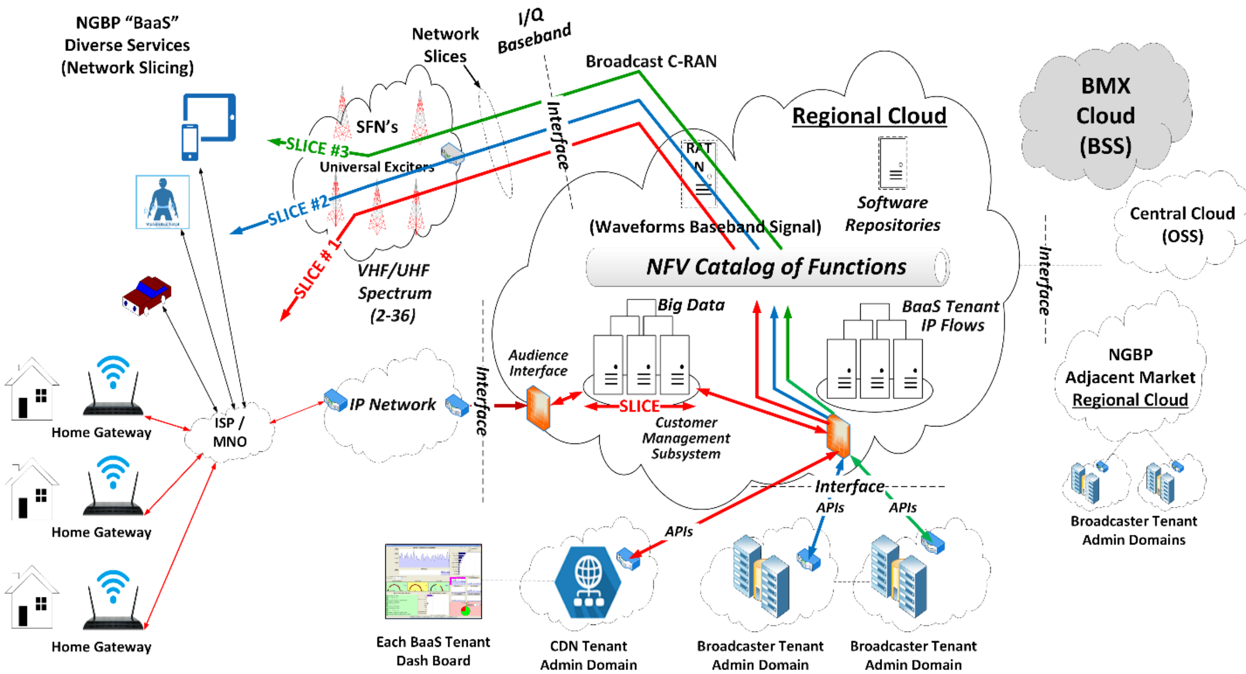

Figure 13 NGBP Hybrid Broadcast / Broadband Network Slicing

Figure 13 shows concept of hybrid broadcast/broadband using intelligence in NGBP. The use case scenario is with two broadcaster tenants and one Content Delivery Network (CDN) tenant in their respective administrative domains. These tenants are under management of the BMX entity (SLA) and MANO with exposed APIs on the interface shown. These tenants could have the option to provide (host) some NFV functions in their own respective administrative domain that are coordinated (chained) with NGBP (NFV Catalog of Functions) to provide flexible network slicing use cases across multiple administrative domains. This is also an envisioned use case for 5G under network slicing [32].

Figure 13 has three broadcast network slices (1, 2, 3) indicated, each serving the diverse services shown. The CDN tenant (partner) can for example provide NFV functions chained together for network slice #1 (red) over broadcast and over the broadband network shown to complement a service, *etc*. See the audience interface and customer management sub-system in regional cloud. Being able to leverage an OTT (ISP/MNO) return channel with the intelligence in the NGBP is a powerful tool for all tenants and could be useful with broadcaster home gateway shown in homes. The home gateway and "Network

[32] NGNM Alliance, 5G Network and Service Management including Orchestration, https://www.ngmn.org/uploads/media/170307_5G_Network_and_Service_Management__including_Orchestration_2.12.7.pdf

Slicing" shown could enable business models to meet consumer expectations without cable and/or satellite service by serving fixed (home) and mobile devices synergistically under NGBP.

A recent report[33] states that 5G went further by introducing a brilliant technology, 'virtualization', which makes it possible for different RAT, RAN and Core entities to be implemented as software on a universal server. This has enabled telecom providers to adopt IT technologies that leverage open source SW/HW, making the communication infrastructure more completely IT-based. Thus, the 5G ecosystem can extend its boundary to embrace new Information and Communications Technologies supporting services such as IT and IoT in addition to more traditional communications. By this reasoning, all telecoms including broadcasting are aggressively seeking ways to transform into a platform provider, media service provider, solution provider or more.

CONCLUSION

Television broadcasting today is tied to an inferior and "rusting" infrastructure, ill-suited to meet the demands of viewers, users and broadcasters. Our industry must evolve to remain relevant and support going concern operations. Whether offering traditional but advanced television services (UHDTV, HDR, 4K, Immersive Audio) or video-rich data (OTT, SVOD, Augmented Reality, VR), the nature of what we do and the means to do it must shift dramatically. For broadcasting, spectrum use is being challenged by the question of 'best utilization.' At the same time technological advances and the capacity to reimagine data distribution will be the savior of terrestrial broadcasting.

Cooperatively bonding stations together through use of a BMX cloud based SDN/NFV infrastructure and enabled by the capabilities of the Next Gen standard provides broadcasters with the ability to both enhance their traditional program content delivery business, and also expand to provide local, regional and national data services with an entree into businesses traditionally provided by others. The new architecture can provide both competition to wireless carriers and a complementary service integrated into their new 5G offerings. Terrestrial DTV technology and the network architecture as we know it today must change fundamentally and moreover be harmonized with a virtualized IP Core network for broadcasters to remain competitive, relevant and perhaps most importantly, to grow their business in the Internet Age.

With the emergence of an "All-IP" wireless digital broadcast standard, the potential to reshape the very nature of broadcast television illuminates new opportunities to leverage a new platform and transform the nature of 'digital bit distribution.' For Sinclair, that is the very notion of the Next Generation Broadcast Platform. The promise of including broadcasting in a converged "5G" aligned future is likely to be inexorable. All data distribution using spectrum must coalesce in the interest of markets seeking the cheapest and highest quality path. The Sinclair vision moves along that path by providing an intelligent, cloud-based entity to 'orchestrate' the bit-flow, agnostic to the nature of the bits, but aware of the provisioning needs to deliver such bits on a true "Quality of Service" basis. That is the essence of the concept we have called the BMX (Broadcast Market Exchange).

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[33] http://www.netmanias.com/en/?m=view&id=reports&no=11609