The Future of Hybrid Fibre Coaxial Cable Network Technology

Where is it going, what can it achieve, and what does the future promise the user?

Supply Nation MEMBER

c-cor

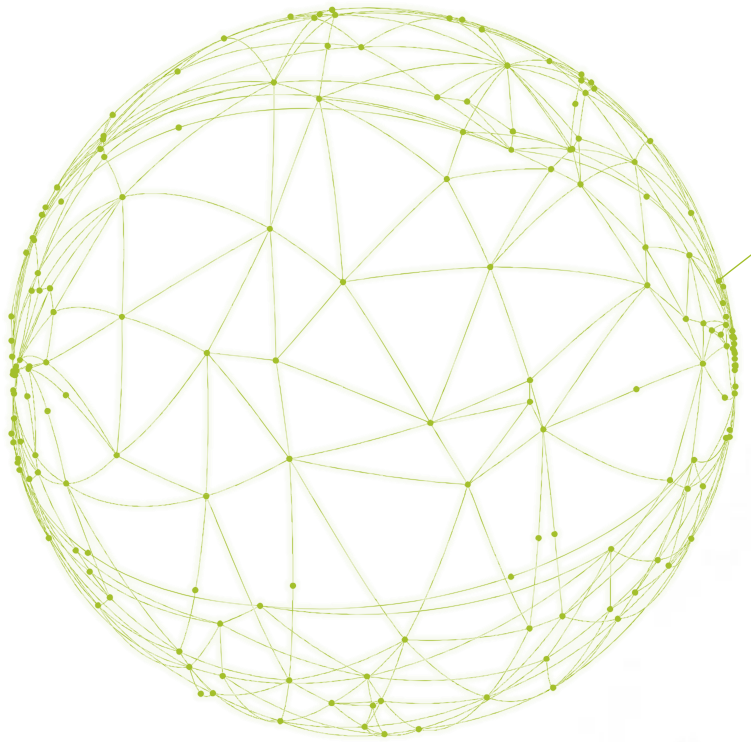
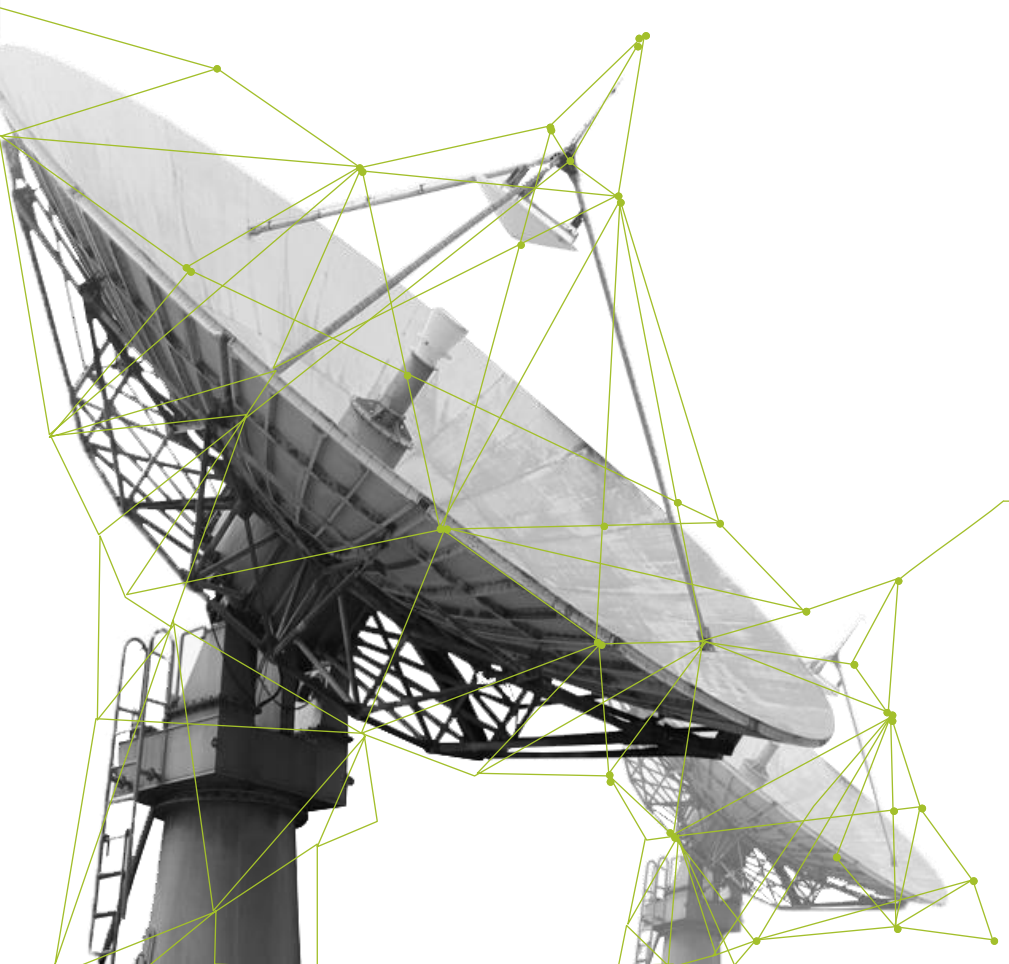
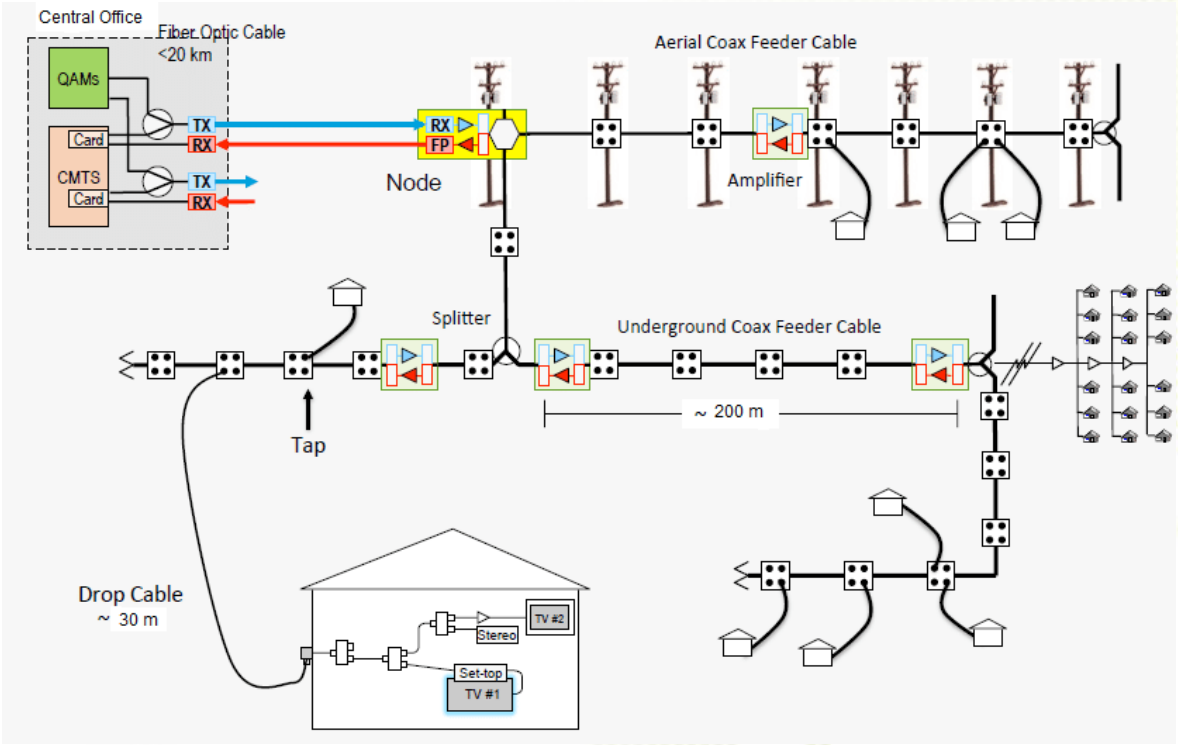


TABLE OF CONTENTS



1. INTRODUCTION

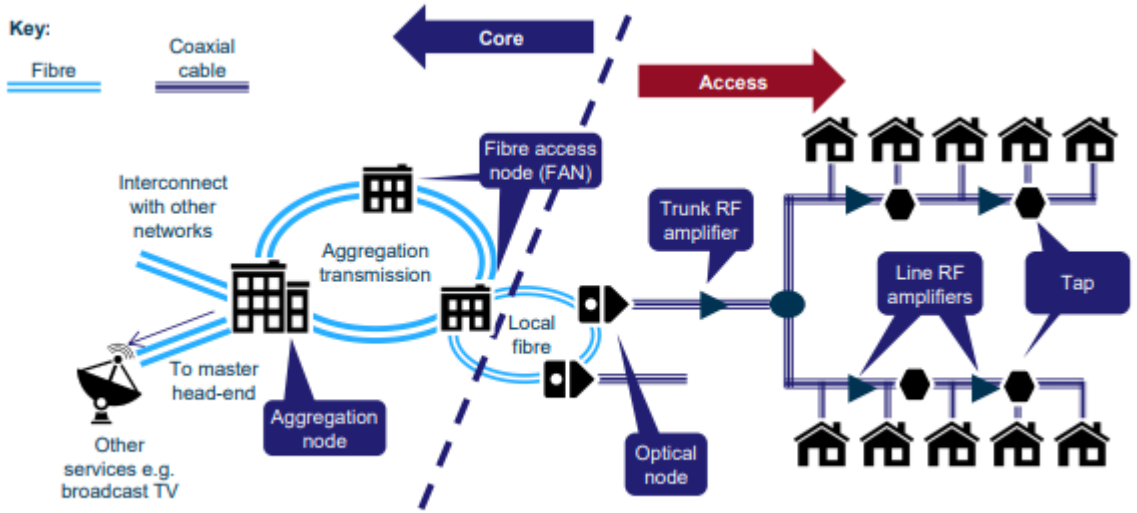
TYPICAL HFC PLANT



https://www.researchgate.net/figure/IPKOs-HFC-Network-Topology_fig2_308918787

FIG. 1

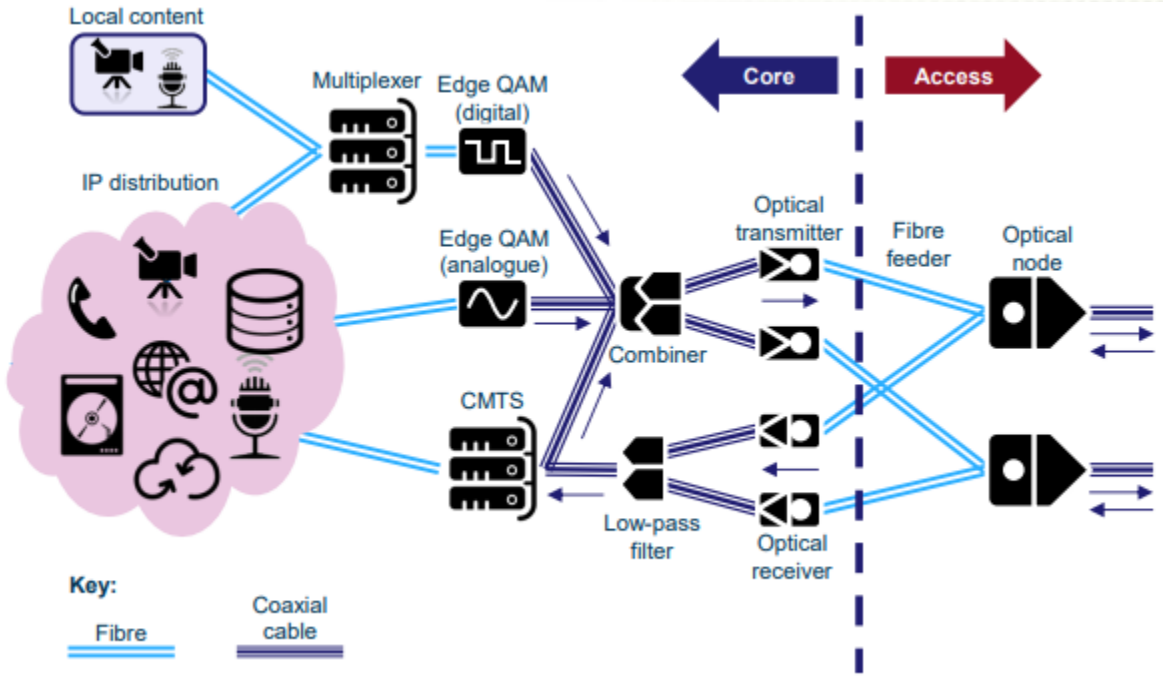
NETWORK OVERVIEW HFC PLANT



"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 80 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 2

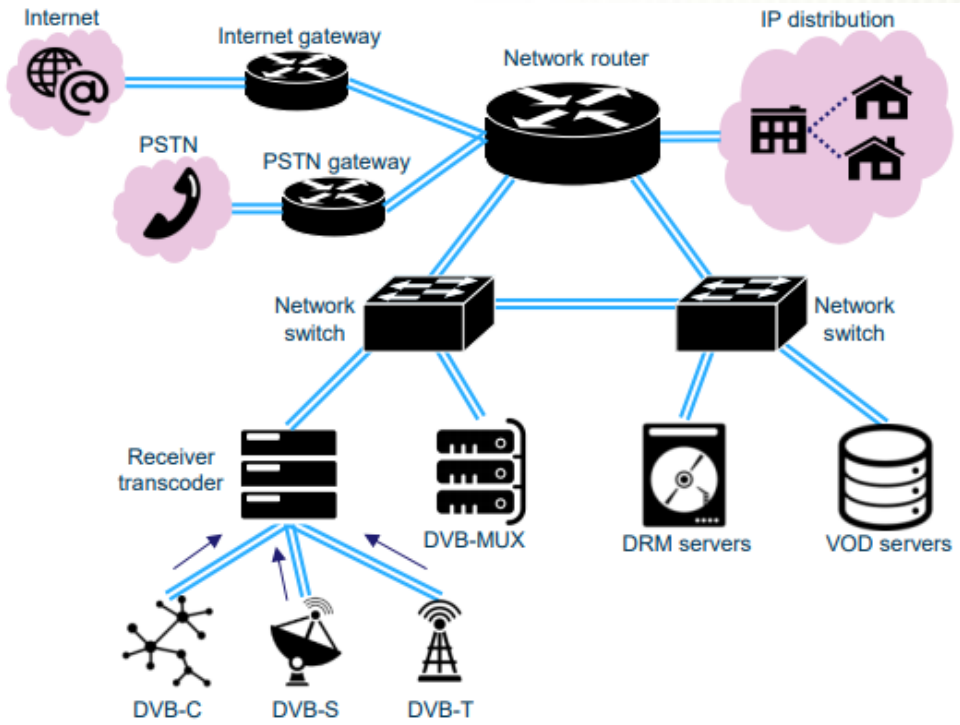
COMBINED FAN AND AGGREGATION NODE



"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 81 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 3

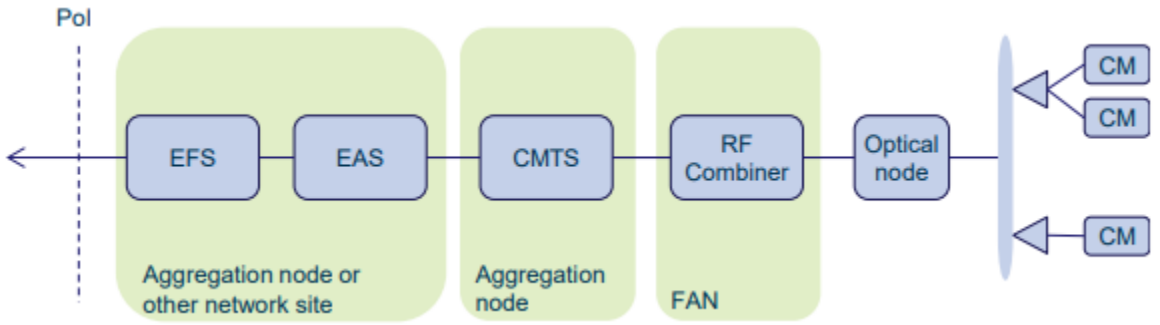
MASTER HEADEND



"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 82 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 4

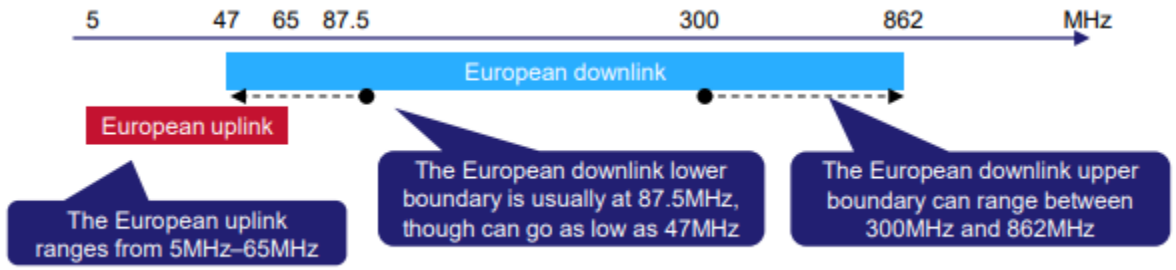
INTERCONNECT WITH RSP'S



"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 83 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 5

BANDPLAN RANGE FOR EUROPEAN CABLE SYSTEMS



"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 86 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 6

TYPICAL SPECTRUM PLAN UNDER EURODOCSIS® 3.0

"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 87 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 7

COVID-19 HAS ACCELERATED THE TRENDS OF NETWORK USERS WORKING FROM HOME (OR ANYWHERE)

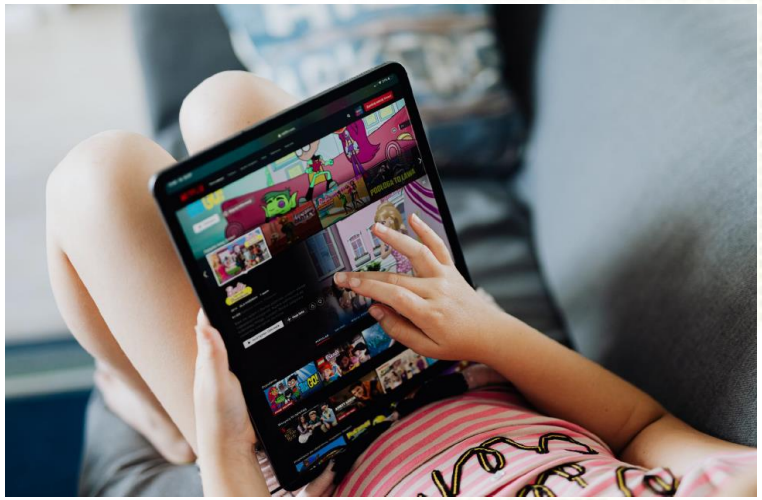
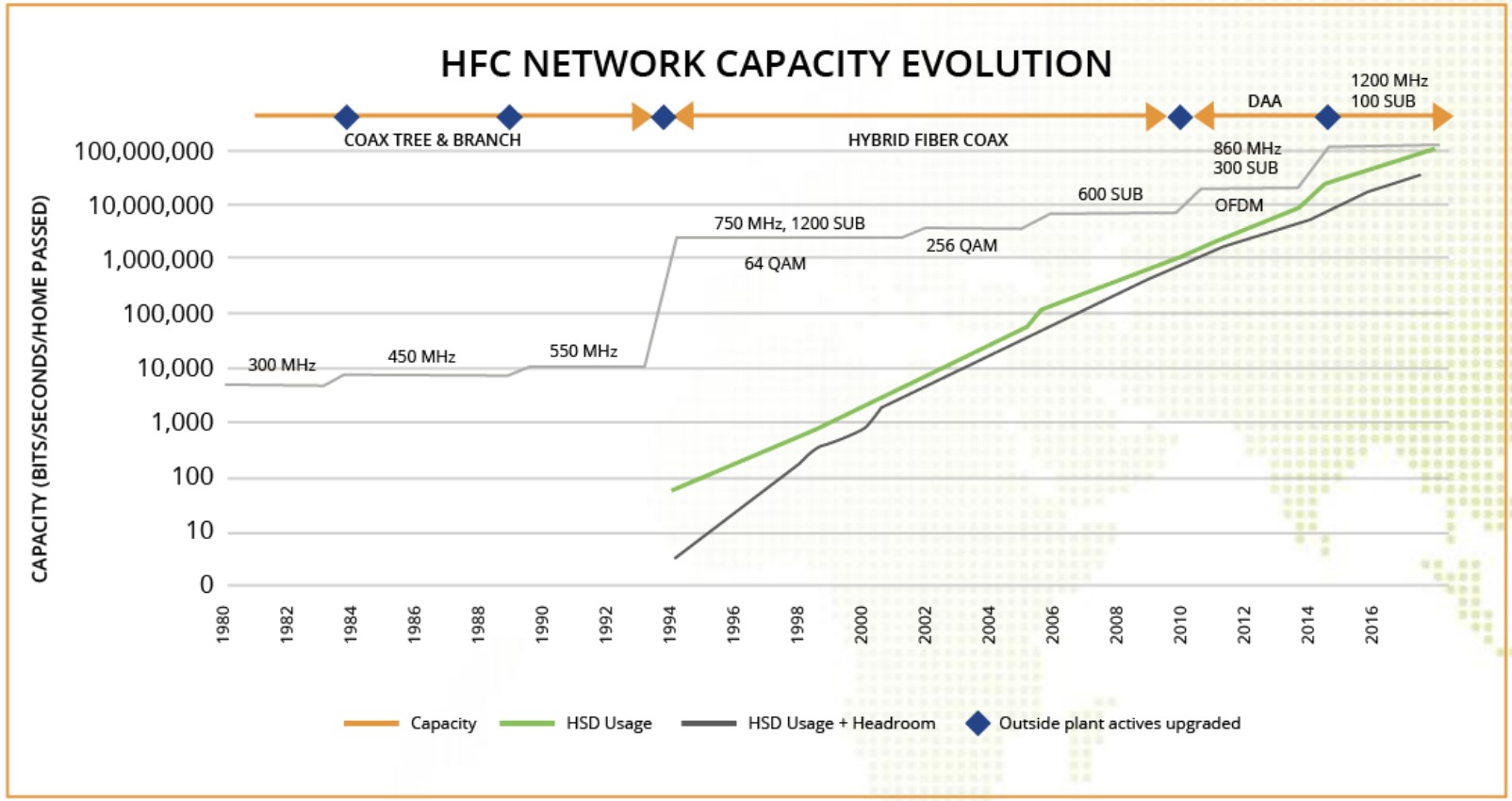


IMAGE 1

HFC NETWORK CAPACITY EVOLUTION



HFC Network Capacity Evolution - https://mktg-webtestext.arris.com/solutions/access-network-evolution-framework/

FIG. 8

DOCSIS® 3.1 AUGMENTATIONS

In the near future, DOCSIS® 3.1 augmentations will expand the spectrum and the spectral efficiency of the HFC network to support (perhaps) ~10 Gbps Downstream bandwidth capacity and ~2 Gbps Upstream bandwidth capacity on a 1.2 GHz plant with a 204 MHz high-split. Discussions are now underway on the topics of Full-Duplex DOCSIS® that may permit even higher Upstream bandwidth capacities in the near future. Future DOCSIS® 3.1 expansions to 1.7 GHz may even permit the HFC network to even support ~15+ Gbps of Downstream bandwidth capacity.

This poses the following questions:-

- *Is the 15 Gbps bandwidth capacity of DOCSIS® 3.1 the last change that we will make to the HFC network?*
- *Is the bandwidth capacity offered by DOCSIS® 3.1 (in its current form) adequate for the long-haul into the future?*

EVOLUTION OF THE HFC NETWORK

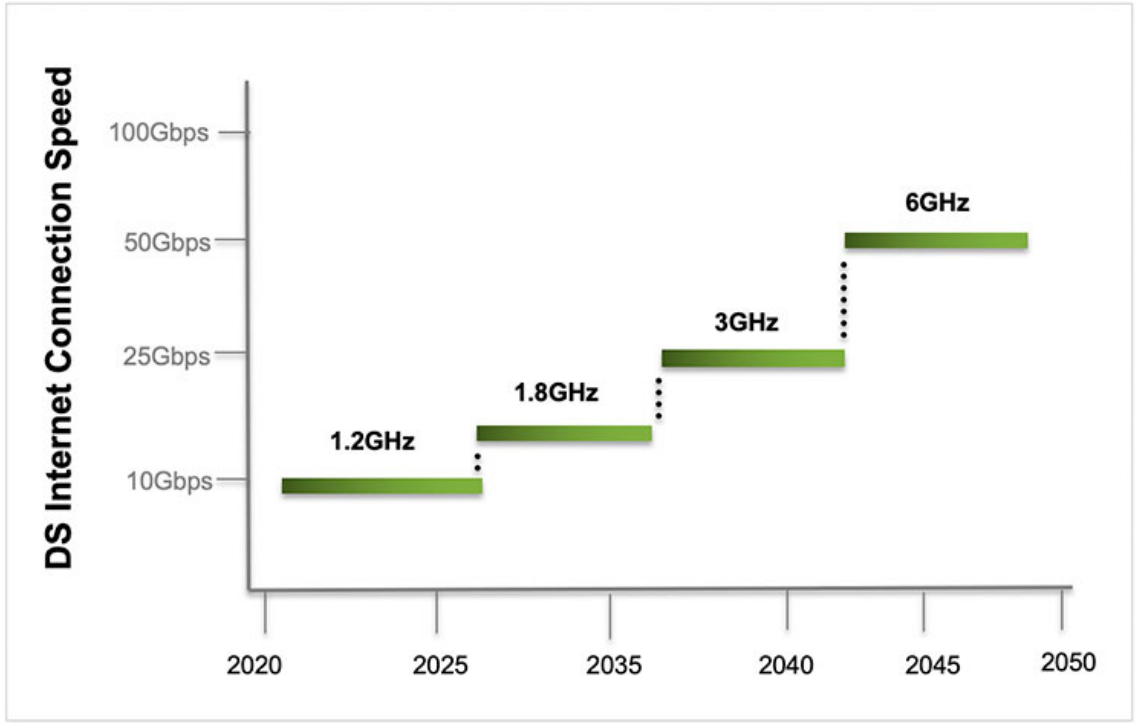
Evolution of the HFC Network

	The First 30 Years	The Next 30 Years
Optics	Analog	Digital
Spectrum Maximum	1.2GHz	3GHz+
Bandwidth Span	56Kb to 1Gb	1Gb to 50Gb
Technology Lifecycle	8-10 years	25 or more years
Architecture	CAA	DAA
Typical Applications	Email, streaming video	Holodecks, telemedicine

2. “The 2050 Project:Part 1,pge. 11 ” - WWW.ATX.COM

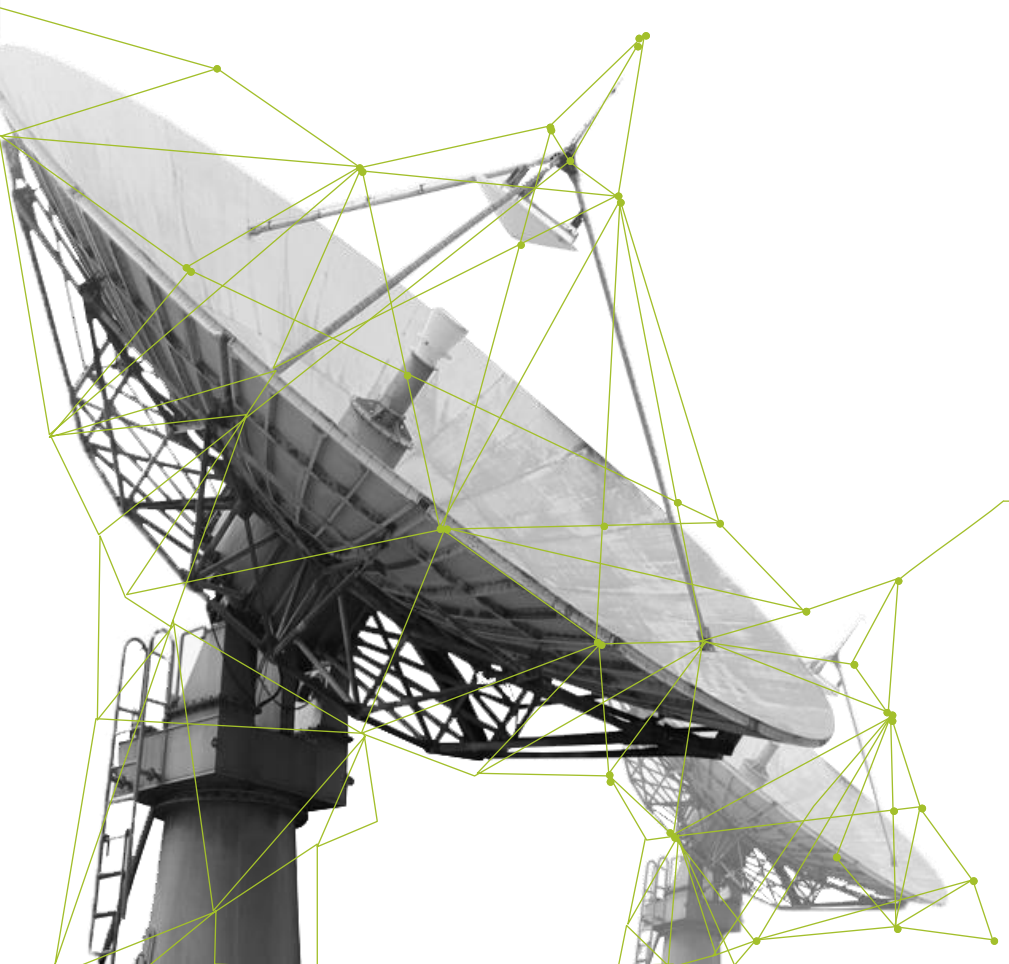
FIG. 9

THE BILLBOARD BANDWIDTH QUESTION



2. "The 2050 Project:Part 1,pge. 6 " - WWW.ATX.COM

FIG. 10



2. THE PAST

IN 2014

John

C-COR

“The media and telecommunications industry is entering a period of rapid change. The change will be driven from consumers and competition.

The consumers of the next decade will likely be those whom have a desire to have any content made available anytime, anywhere and to any device “.

CONTENT ANYWHERE, ANYTIME, AND TO ANY DEVICE –

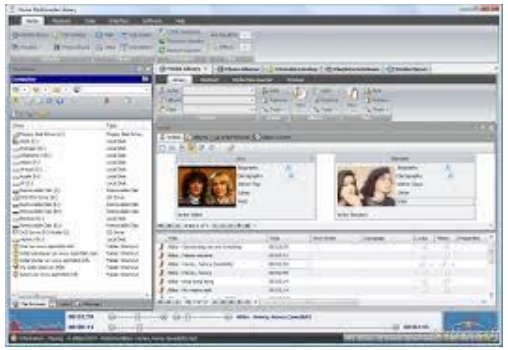


IMAGE 2

THE TRANSITION FROM BROADCAST SERVICE DELIVERY TO UNICAST DELIVERY

IMAGE 3

NO LONGER A RECIPIENT OF CONTENT, BUT NOW A CREATOR

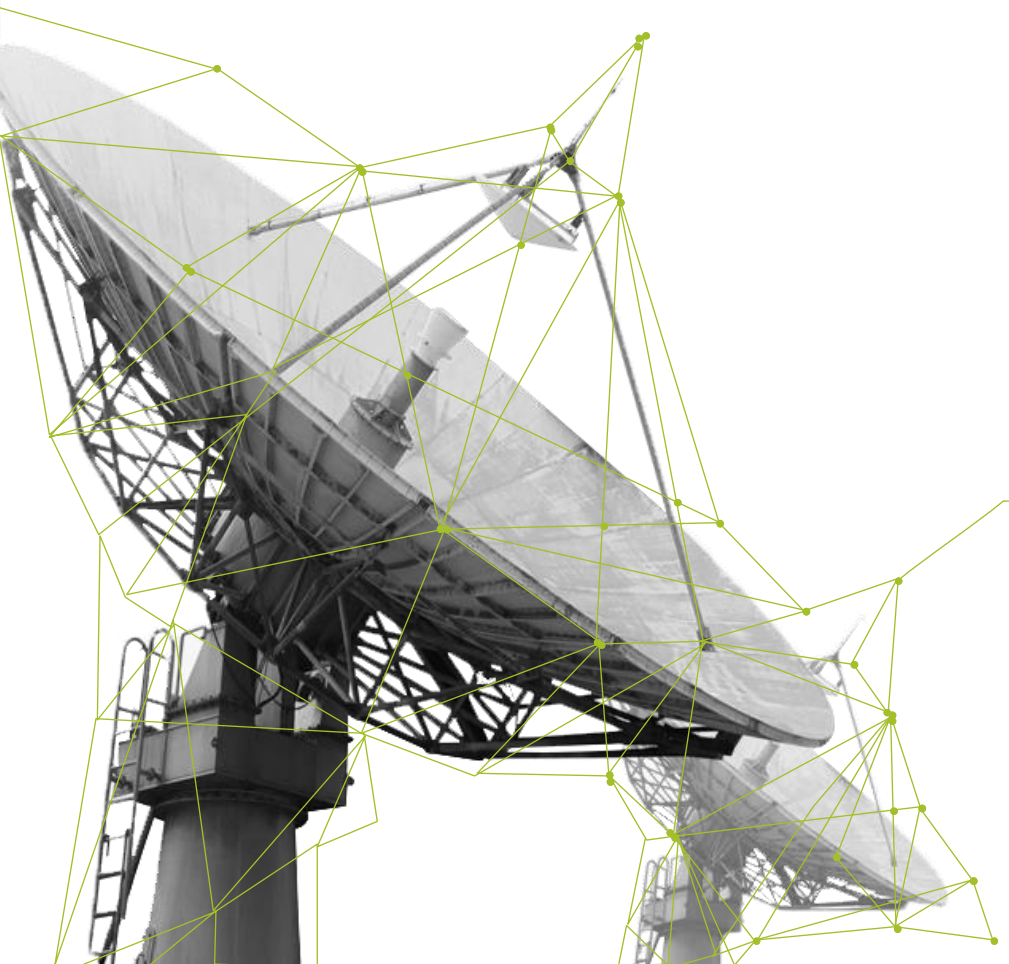
Creator / Distributor

IMAGE 4

VIDEO STREAMING IS THE NEW TV

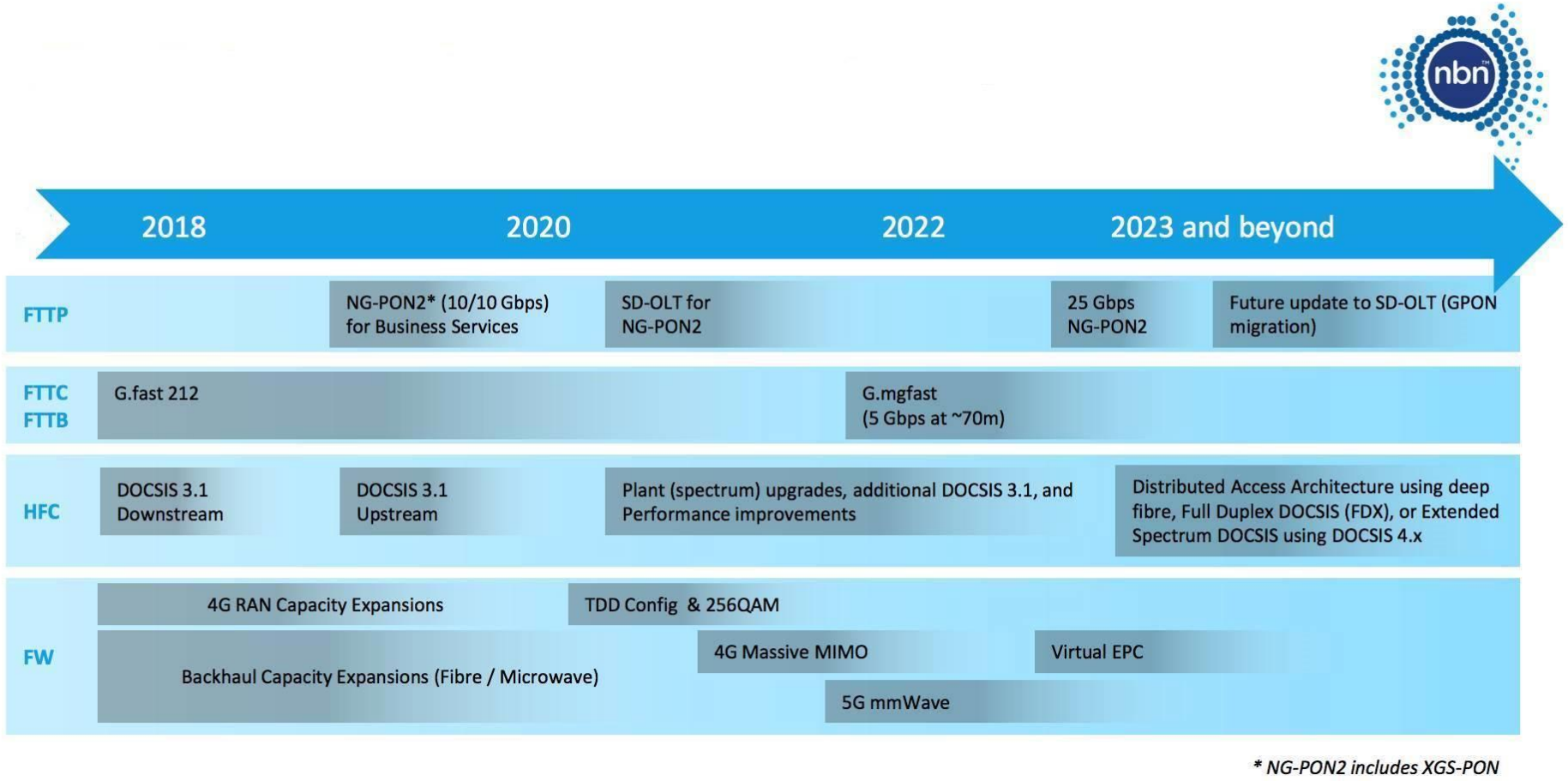
Jamie

IMAGE 5



3. CURRENT

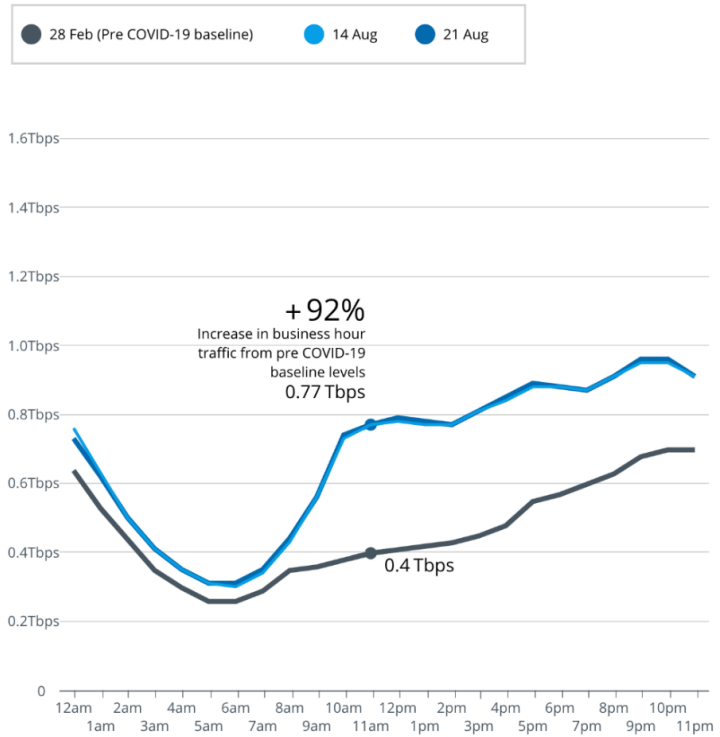
FUTURE TECHNOLOGY OPTIONS - AN AUSTRALIAN PERSPECTIVE



THROUGH TO 2023 AND BEYOND - HTTPS://I.NEXTMEDIA.COM.AU/NEWS/NBN_TECH_OPTIONS.PNG. IT NEWS

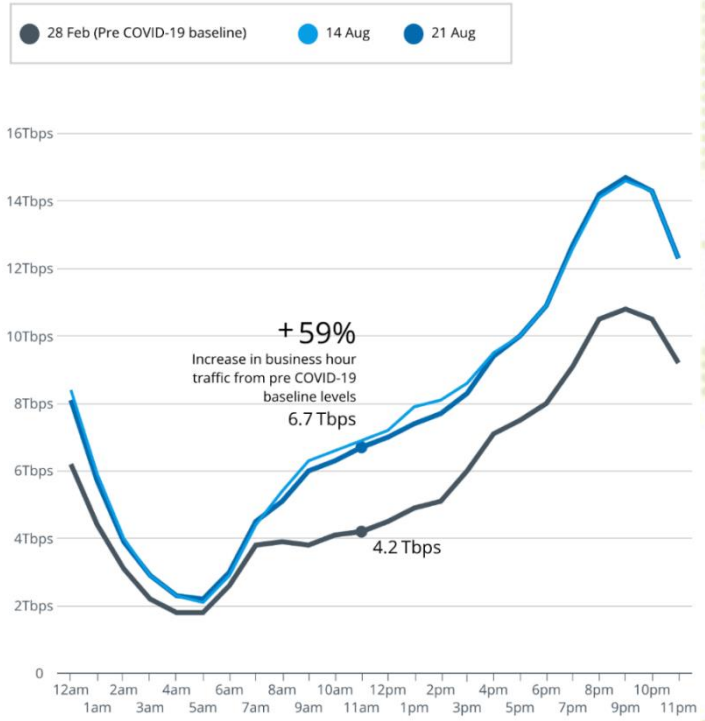
FIG. 11

TRAFFIC SPIKES IN NETWORK USAGE



Upstream network usage

Upstream network usage, at 11am on Friday, 14 Aug increased 92% compared to Friday 28 Feb (Pre COVID-19 baseline



Downstream network usage

Network usage, at 11am on Friday, 21 August increased 59% compared to Friday 28 Feb (Pre COVID-19 baseline).

Source: https://www.nbnco.com.au/corporate-information/about-nbn-co/updates/dashboard-july-2020

FIG. 12

PEER TO PEER (P2P)

IMAGE 6

The explosion in the use of peer-to-peer (P2P), and the sudden increase of YouTube and social networking (eg. Facebook and Tik Tok)…….

……..and the fact we are collaborating for business purposes as well as personal reasons and sharing not only "moments" but sharing significant time in REAL time expertise……eg. On demand Telemedicine, on demand consultancy etc..

has further driven the reality that telecommunication providers and cable operators have increasingly become not only content distributors to the home, but also increasingly, "from" the home, and home office.

VIRTUAL (ARTIST) COLLABORATIONS

Entertainment Industry

IMAGE 7

“Our inability to entertain in person, in groups, on stage, in arenas, or even to travel,

has led to the intelligent and thoughtful development of “Virtual” artist collaborations”.

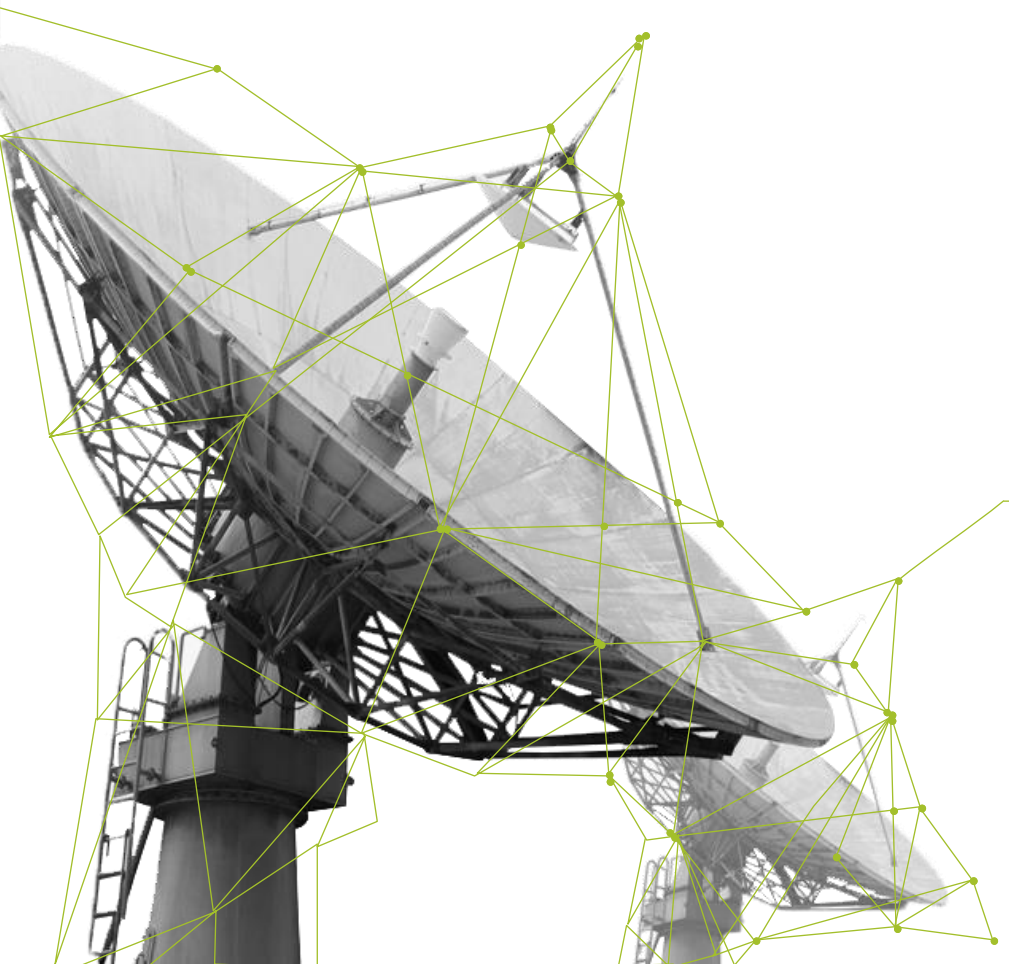
YOUNGER VIEWERS – GEN Z

GenZ

IMAGE 8

I like to stream when I am not on YT, Social Media or gaming platforms…

I have no loyalty to cable whatsoever and no patience for commercials on TV



4. THE FUTURE

A LOOK AHEAD

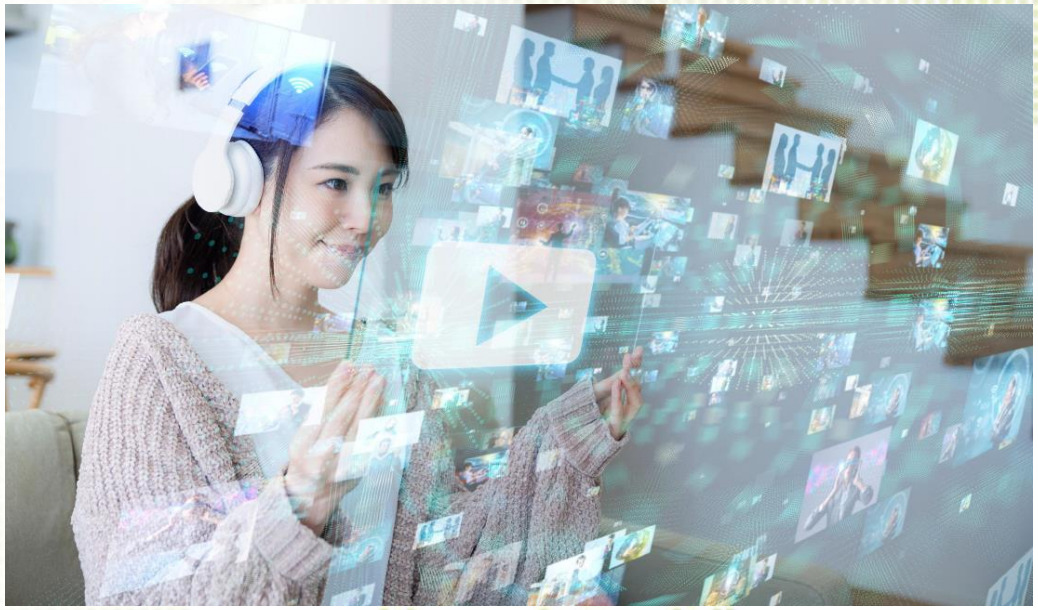


IMAGE 9

MULTI NETWORK UNIFICATION

IMAGE 10

AN IMMERSIVE FUTURE

IMAGE 11

IMMERSIVE EDUCATION ?

IMAGE 12

SMART TV VARIANTS PAIR WITH VR EYEWEAR AND HEADSETS

IMAGE 13

VIRTUAL REALITY + AUGMENTED REALITY + MIXED REALITY

IMAGE 14

WIRELESS 5G/6G

IMAGE 15

5G XHAUL

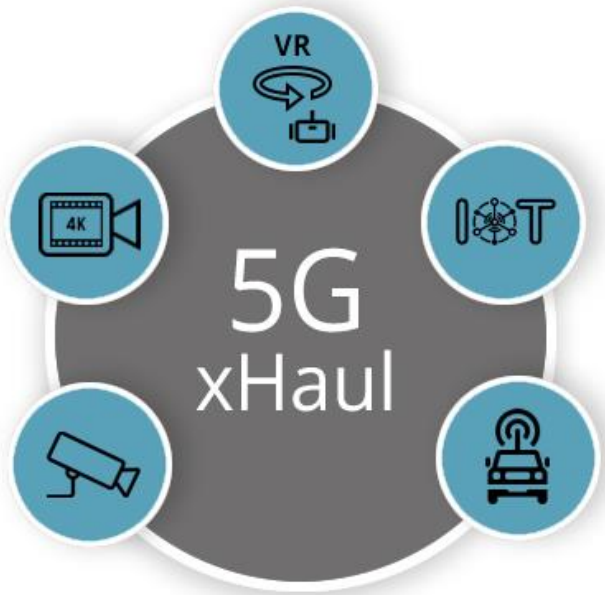


IMAGE 16

WIFI 6 /6E AND 7

IMAGE 17

FTTC / FTTB - G.FAST 212

G.FAST IS A BASEBAND TECHNOLOGY WHICH USES TWISTED PAIR IN A FTTC / FTTB ARCHITECTURE –

AN EVOLUTION OF ADSL/VDSL TECHNOLOGY.

FIBER VS COAX

	Fiber	Coax/HFC
Capacity	√	X
Coverage	X	√
Convenience	X	√
Cost	X	√

****If MSOs could undergo a coax-to-glass transition with a snap of their fingers, they would do so in a second. Fiber is the undisputed option for new builds and instances where portions of the coax plant need to be replaced. The real question facing MSOs, is not if they should move to an all-fibre infrastructure, but how quickly.*

2. "The 2050 Project:Part 1, pge 8" - WWW.ATX.COM

FIG. 1

CABLELABS INDUSTRY ROADMAP

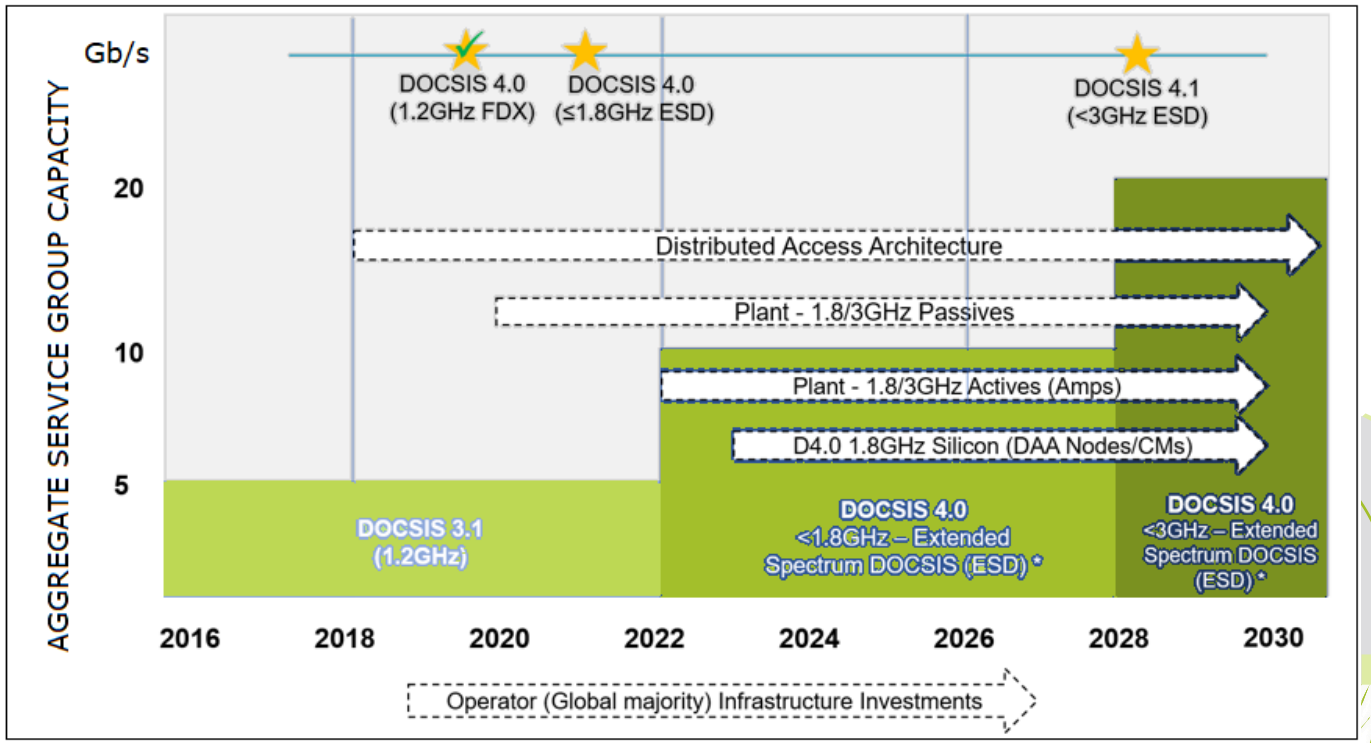


FIG. 15

A LIMITING FACTOR IN NETWORK UPGRADES

MSO

There has always been a clear divide between upstream and downstream splits (42/54;55/70;65/85;85/105 and 204/258)

This separation has now become a limiting factor when upgrading the network since each upgrade requires new filters and additional labour

THE ROAD TO DOCSIS® 4.0

MSO

“A key feature of of the new DOCSIS® 4.0 specification is expanding our HFC cable plant from todays 750MHz/862MHz/1GHz to 1.8GHz (1.7494)

This will nearly double the spectral capacity of todays HFC networks”.

SOME QUESTIONS

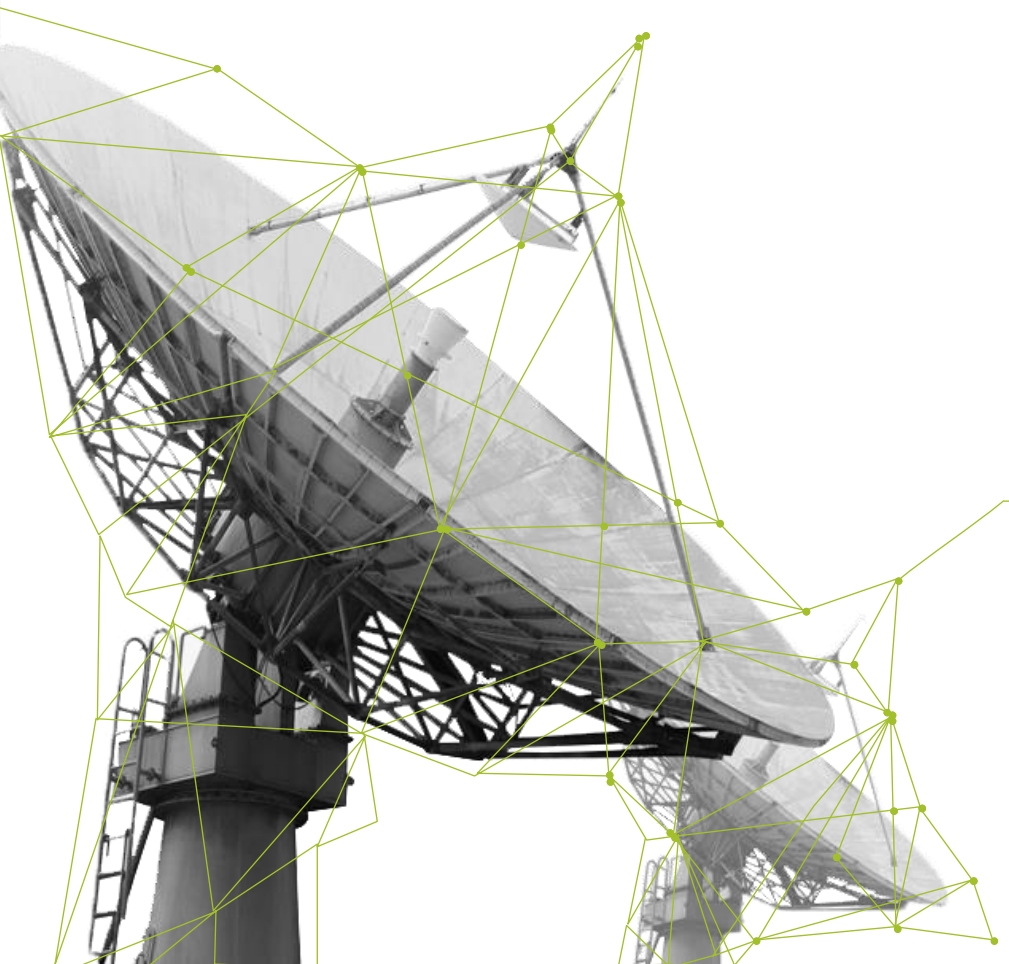
MSO

Is the bandwidth capacity of DOCSIS® 3.1 (in its current form) adequate for the long haul into the future?

Is the 15Gbps bandwidth capacity of DOCSIS® 4.0 the last change that we will make to the HFC network?

FULL-DUPLEX DOCSIS® & THE PROMISE OF MORE BANDWIDTH

- *Discussions underway on the topics of FULL-Duplex DOCSIS® suggest that it may permit even higher Upstream bandwidth capacities in the near future.*
- *Future DOCSIS® 4.0 expansions to 1.79494GHz may even permit the HFC network to support 15+ Gbps of Downstream bandwidth capacity.*
- *Fully realizing this potential, however, means making changes to the way the industry approaches architecture, which in turn requires new technology and techniques.*



6. RETHINKING THE HFC

PATHWAY CHOICES

MSO’s

Two Choices

1. *The MSO must invest heavily into a new last mile infrastructure (and Technology) that will replace the legacy HFC. (Revolutionary)*

2. *The MSO requires to continue incremental investments in the existing Last Mile Delivery infrastructure and find ways to augment the capacityof the legacy HFC…….(BAU) (Evolutionary)*

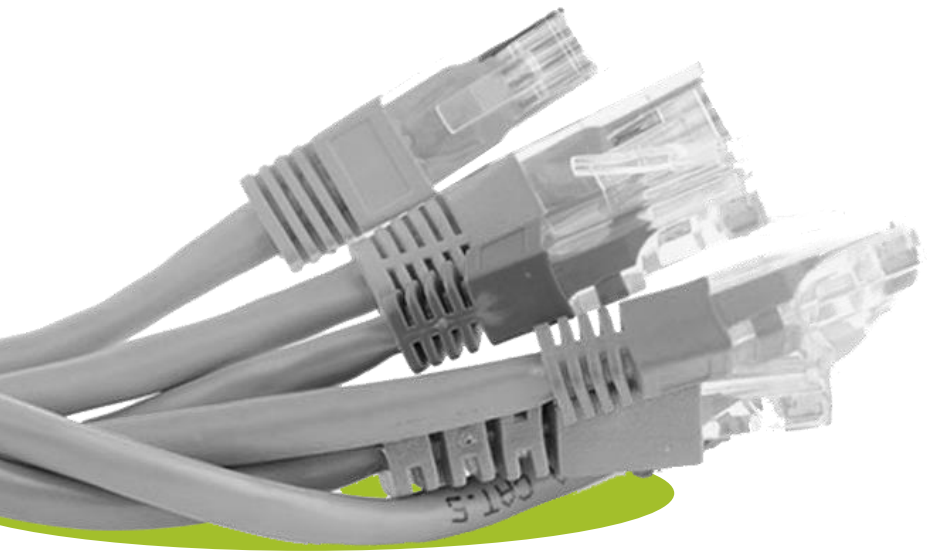
LIMITATIONS TO TODAYS HFC DESIGNS

MSO

These latest technological advances in DOCSIS® 4.0, provide us with an opportunity to rethink how we look at HFC network design.

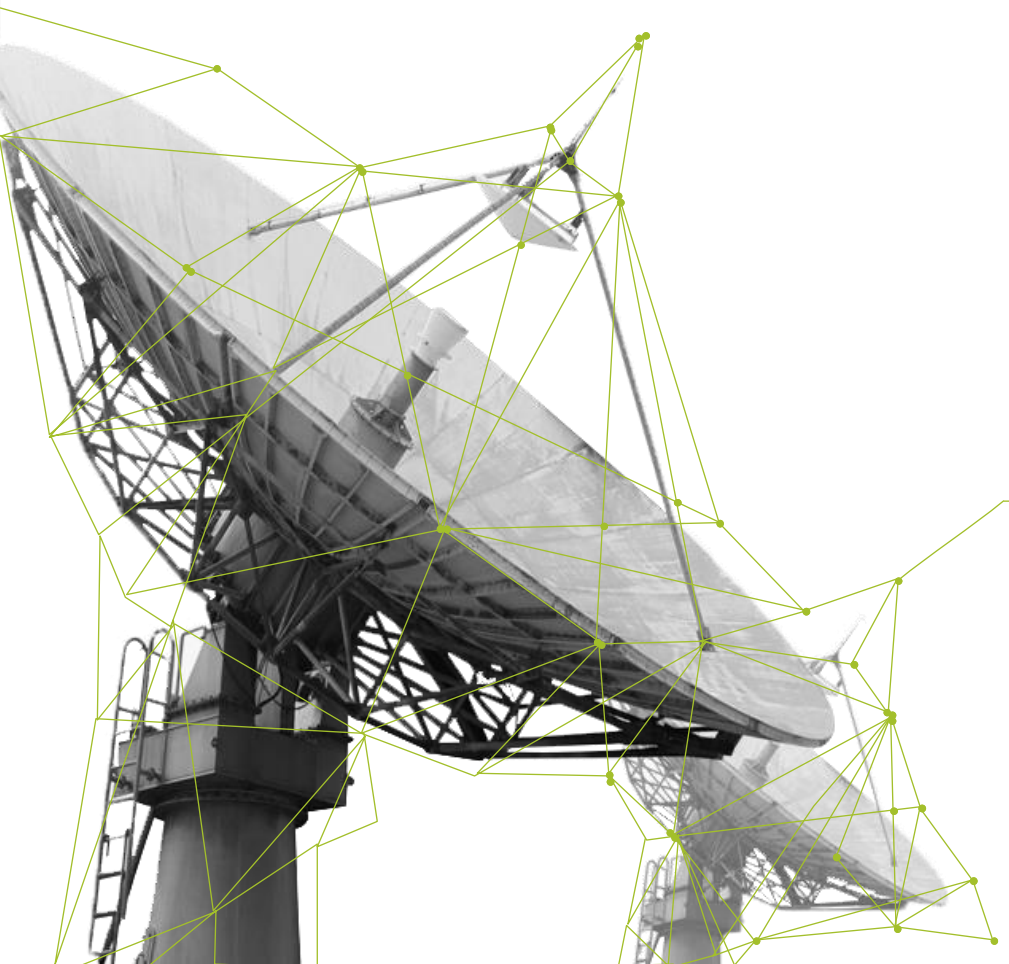
We recognise that cable has a long and useful life ahead of it.

MOVE TO DOCSIS® 4.0 (THE PATH TO 10G PLATFORM)



“Is this a paradigm shift in the future of connectivity across platforms?”

“A fully realized connected network that enables all the different use cases and provides ubiquitous coverage through a seamless experience relying on multiple technologies and choices……”

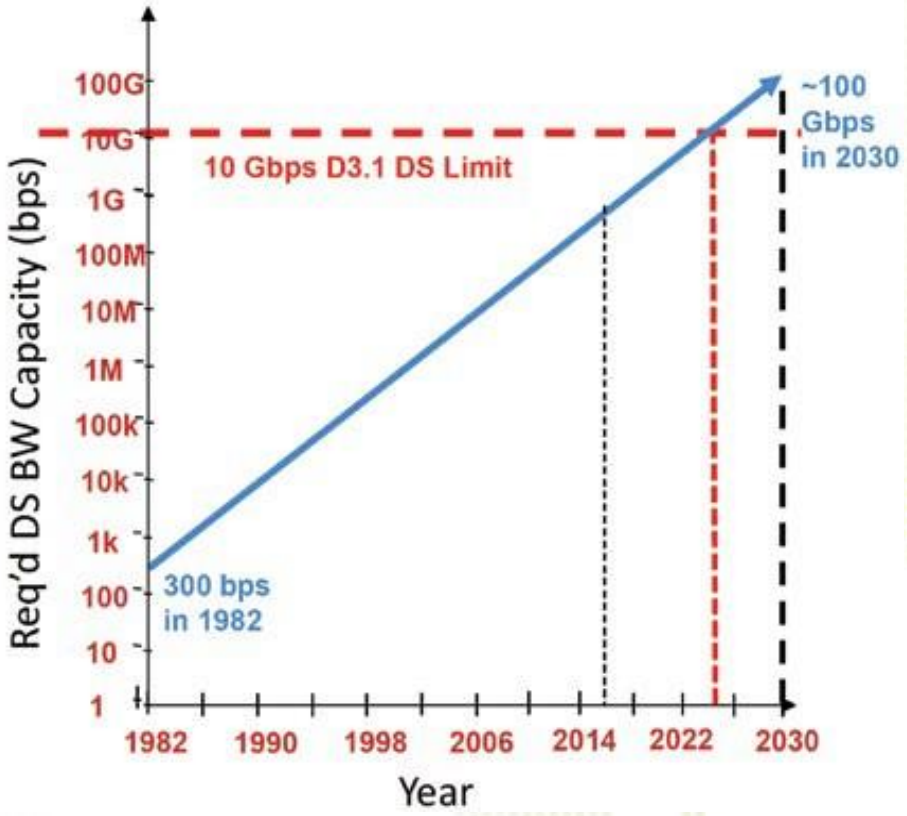


7. DRIVERS FOR BANDWIDTH

CUSTOMER EXPERIENCE (QOE) VS QOS THRESHOLDS

“One of the technology strategy drivers for network operators today is the “Customer Experience”, and the importance of alignment of network thresholds to the customer experience”.

EVER GROWING DEMAND FOR CAPACITY



DOWNSTREAM BANDWIDTH VS YEAR

(TYPICAL 100 SUBSCRIBER SERVICE GROUP)

"USING DOCSIS® TO MEET THE LARGER BW DEMAND OF THE 2020 DECADE AND BEYOND,PGE.4 "
- TOM CLOONAN, AYHAM AL-BANNA, FRANK O'KEEFE

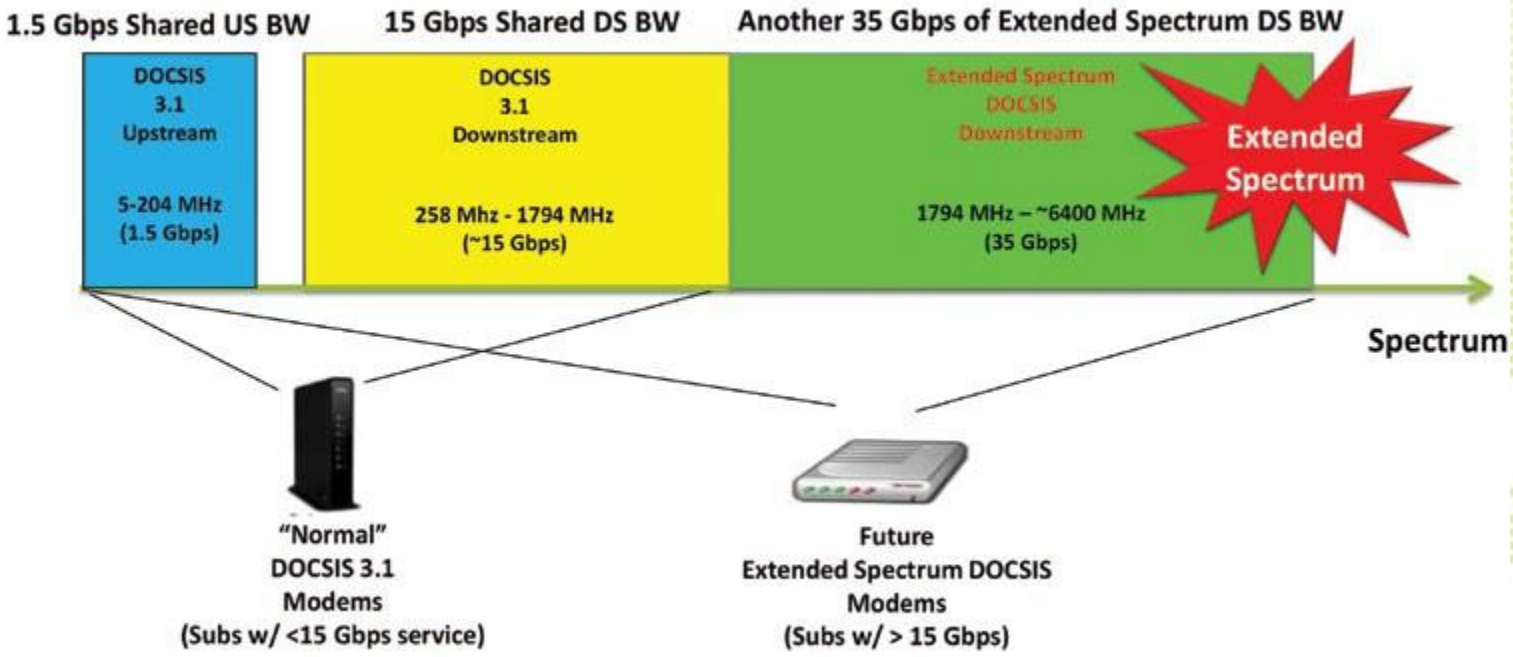
FIG. 16

EXTENDED SPECTRUM DOCSIS®

Basic Idea Behind ESD

One approach focusing on the second path defined above is an approach known as "Extended Spectrum DOCSIS®." The idea is quite simple. Rather than change out the entire HFC plant for a new technology to increase their bandwidth capacity levels, MSOs can instead choose to continue to use the HFC plant by extending the spectrum that supports DOCSIS® 3.1 OFDM blocks beyond the 1.794 GHz limit that is specified in the DOCSIS® 3.1 specification today (see Figure below). The top frequency in the Extended Spectrum might be 3 GHz or 6 GHz or 12 GHz or higher. The actual top-end frequency and bandwidth capacity that can be utilized will undoubtedly be function of the manner in which the signals are delivered to the home. (Several different techniques will be outlined below).

ESD EXTENDED SPECTRUM DOCSIS®



Extended Spectrum DOCSIS® in Spectrum Offering ~50 Gbps in ~6 GHz

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge.6 "
- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 17

HFC PLANT FOR ESD SYSTEMS

"Extended Spectrum DOCSIS® would require that several changes be made within the typical HFC network. Obviously, the HFC plant must have the ability to transmit and pass the higher-frequency signals from the head-end and across the fibre portion of the plant, through the fibre node, across the coaxial distribution leg of the plant, through amplifiers and taps, across the coaxial drop portion of the plant, through the coaxial in-home network, and to the modem in the home".

ESD AND HFC PLANT

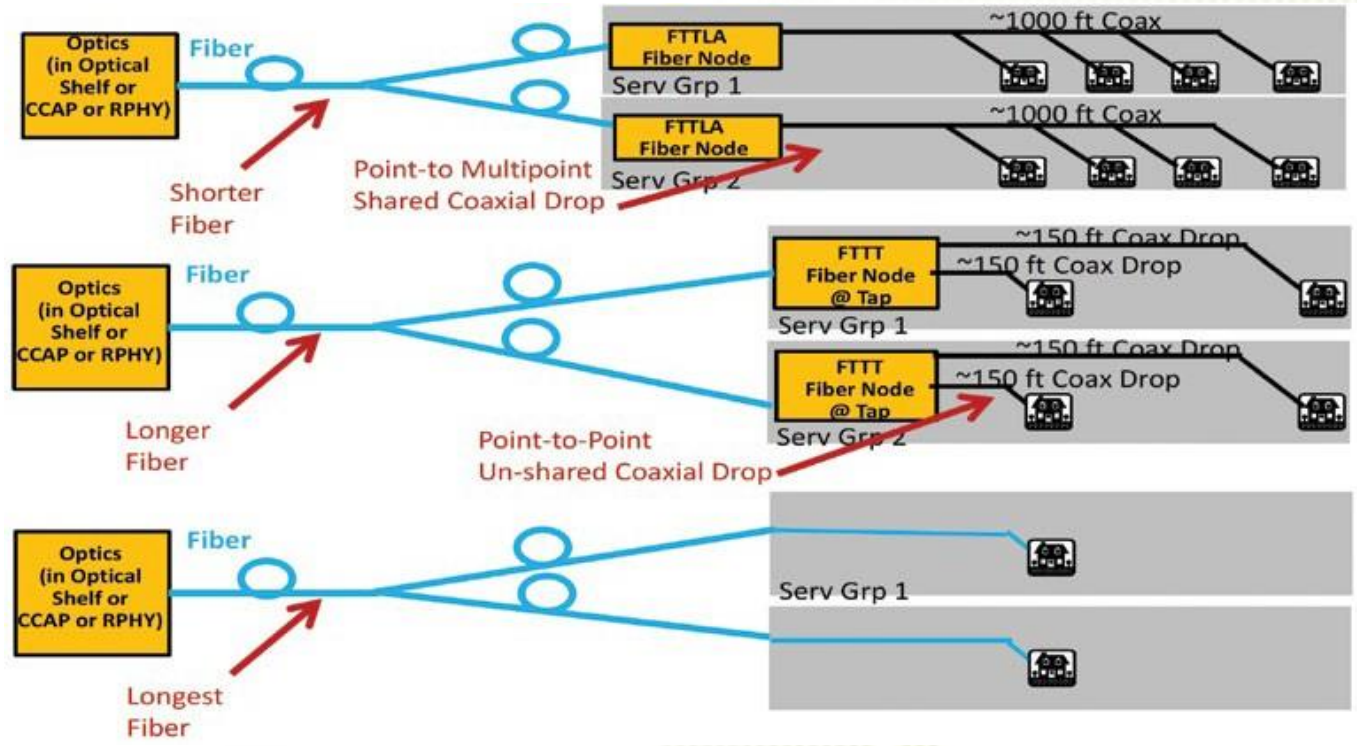
There are many ways to pass these Extended Spectrum DOCSIS® signals through these elements. While it is theoretically possible for high-frequency amplifiers to be designed for passing these signals, the authors believe that most MSOs will likely prefer to wait until their HFC plants have been converted to Node+0 fibre Deep architectures before Extended Spectrum DOCSIS® will be considered as a desirable and feasible technology. (Note: This then eliminates the cost of upgrading many amplifiers, taps and passives to the higher frequencies required for the Extended Spectrum network).

It seems fortuitous that many MSOs predict that they may be performing node splits down to Node+0 architectures before or around the same time that the 10-15 Gbps DOCSIS® 3.1 systems will be 'running out of gas'. (Note: It is also possible for MSOs to get to Node+0 architectures even if they keep their service groups large).

"As seen in Figure 17, it is expected that the required bandwidth capacity of a typical Service Group will exceed the available DOCSIS® 3.1 bandwidth capacity in the early-to mid-2020's. That is likely to be the time-frame when Extended Spectrum DOCSIS® may prove to be valuable. It is also the time-frame when Moore's Law silicon improvements will likely permit Extended Spectrum DOCSIS® systems to be deployed.

This 'perfect storm' of events implies that the early 2020's may be a perfect time to consider for initial deployments of Extended Spectrum DOCSIS® systems. Once an MSO begins to deploy Node+0 fibre Deep architecture designs, many variants of Extended Spectrum DOCSIS® systems could be envisioned." (5.Tom Cloonan, Ayham Al-Banna, Frank O'Keefe)

FTTLA AND FTTT



Variants of HFC Plant Configurations for Extended Spectrum DOCSIS® Delivery

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge. 8 "
- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 18

DISTRIBUTED ACCESS ARCHITECTURE (DAA) FOR EXTENDED SPECTRUM DOCSIS® SYSTEMS

Extended Spectrum DOCSIS® offers a very flexible design. Due to this flexibility, it should be able to work very well with traditional Amplitude Modulated Optical signals being carried over the fibre portion of the HFC network. (Note: This is the type of solution that would be used within the RFoG solutions described in the previous section).

However, nonlinear optical effects resulting from interactions between lambdas on any lengthy wavelength-division multiplexed fibre may reduce the SNR values and reduce the throughput of the Extended Spectrum DOCSIS® system.

As a result, MSOs may alternatively choose to use Distributed Access Architectures (DAAs) to deliver the signals over the fibre portion of the HFC network. With DAAs, the fibre carries digital optics (Ethernet or xPON signals) from the head-end to the fibre Node, and the fibre Node produces the Amplitude Modulated signal that is ultimately transmitted over the coaxial portion of the HFC network. [5.Tom Cloonan, Ayham Al-Banna, Frank O'Keefe]

Two different variants of DAA architectures are being considered by MSOs—Remote PHY architectures and Remote MACPHY architectures.

Extended Spectrum DOCSIS® systems could be built using either of these DAA variants. In both cases, there are several benefits that would result. First, the use of a DAA approach would ensure that the SNR of the signals would not be significantly reduced by the nonlinearities within the fibre portion of the HFC network. Second, the use of DAA systems would help to reduce the power and space requirements in MSO head-ends when fibre deep solutions have created the need to support many small Service Groups. Third, the use of DAA systems (and digital optics) would also permit MSOs to place more lambdas on their wavelength-division multiplexed fibres. Fourth, the use of DAA systems (and digital optics) eliminates the presence of OBI within the digital fibre (since OBI only occurs in Amplitude Modulated optical systems).

Because of all of these reasons, MSOs who move to Extended Spectrum DOCSIS® will have the option to use either centralized or distributed access architectures.

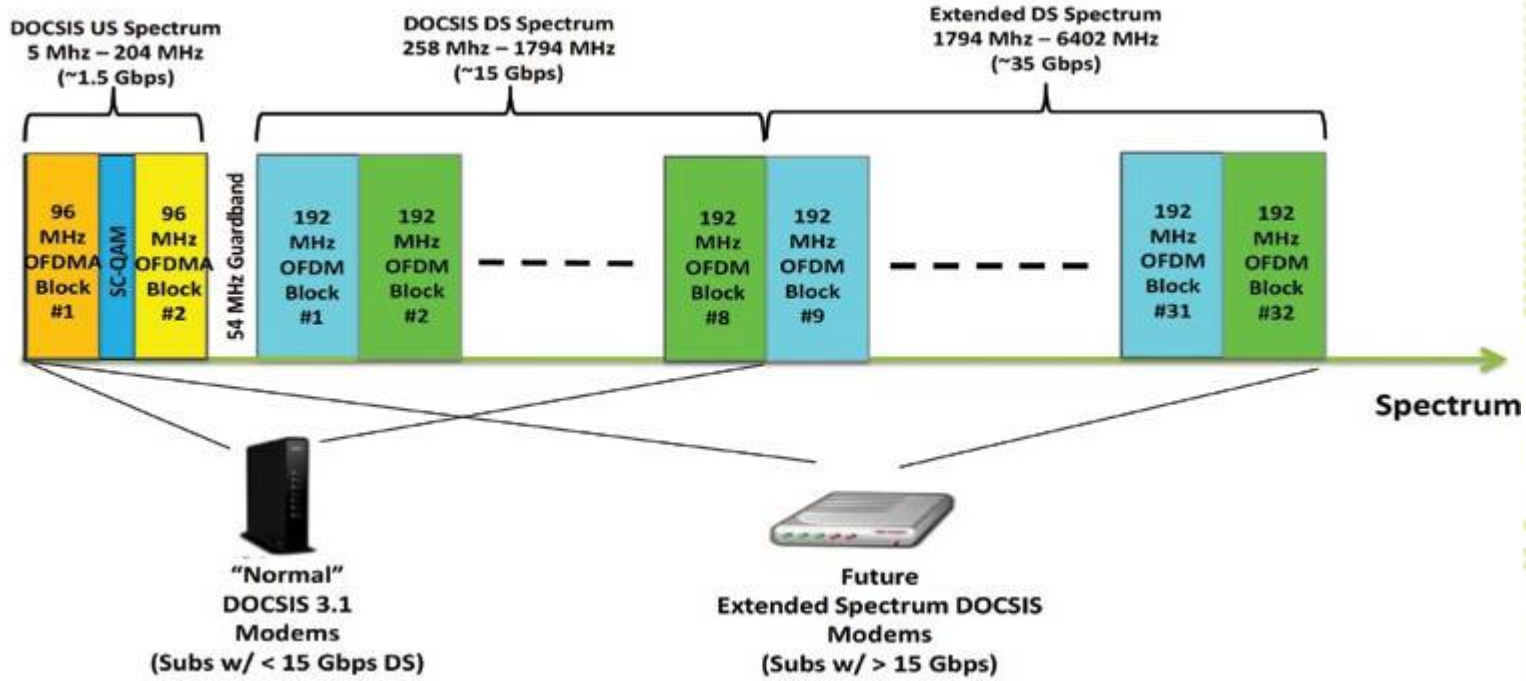
SPECTRUM CONSIDERATIONS FOR ESD DOCSIS® SYSTEMS

With Node+0 systems in place, MSO networks will be ready to carry Extended Spectrum DOCSIS® signals. The signals themselves may take the form of a stack of 192 MHz OFDM Downstream blocks (or a stack of 96 MHz OFDMA Upstream blocks) that inhabit regions of the spectrum beyond 1794 MHz.

The actual amount of spectrum that might be useable for this stack of OFDM/OFDMA blocks is a function of many parameters, including the signal launch power, the noise power injected on the fibre, the length of the fibre, the number of lambdas on the fibre, the wavelengths of the multiplexed lambdas, the noise power injected on the coax, the length of the coax, the attenuation of the coax, the amount of loss in taps, the amount of loss in splitters, modem receiver noise figure, etc.

Thus, depending on the design of the Node+0 system, different spectral widths will be allowed to carry Extended Spectrum DOCSIS® signals. Thus, it is possible that Extended Spectrum DOCSIS® systems of various flavors could be deployed differently by different MSOs. Some may choose to limit Extended Spectrum DOCSIS® operation to ~2.5 GHz. Others may choose to limit Extended Spectrum DOCSIS® operation to ~7 GHz. Still others may choose to push Extended Spectrum DOCSIS® operation all the way to ~10-25 GHz. In each case, the HFC plant must be appropriately conditioned (creating deeper fibre runs and shorter coaxial runs) to guarantee successful OFDM and OFDMA operation.

ASYMMETRICAL EXTENDED SPECTRUM DOCSIS® IN 2-BAND FDD SPECTRUM

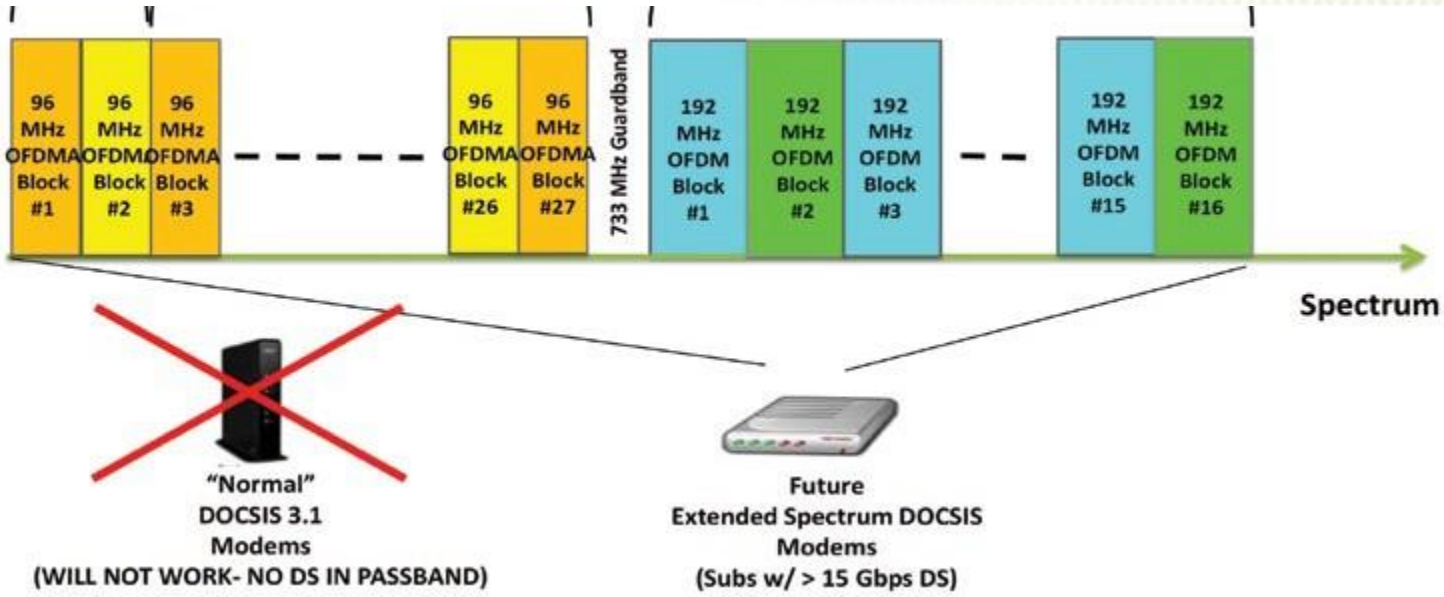


Asymmetrical Extended Spectrum DOCSIS® in 2-band FDD Spectrum Offering

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge 11"- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 19

SYMMETRICAL EXTENDED SPECTRUM DOCSIS® IN 2-BAND FDD SPECTRUM

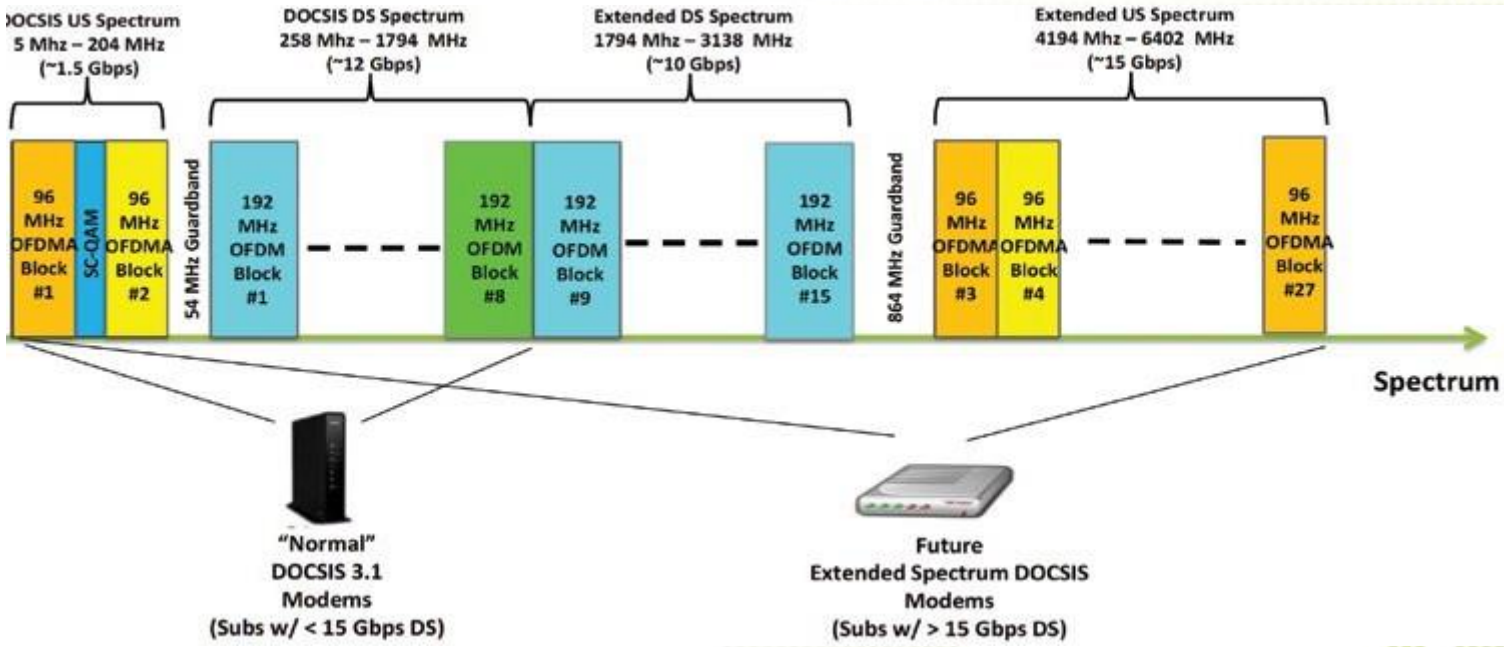


Symmetrical Extended Spectrum DOCSIS® in 2-band FDD Spectrum Offering ~20 Gbps x ~ 20 Gbps US in ~6.4 GHz

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond,pge. 11"- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 20

SYMMETRICAL EXTENDED SPECTRUM DOCSIS® IN 3-BAND FDD SPECTRUM



Symmetrical Extended Spectrum DOCSIS® in 3-band FDD Spectrum Offering ~22Gbps DS x ~16.5 Gbps US in 6.4 GHz

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge.12 "- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 21

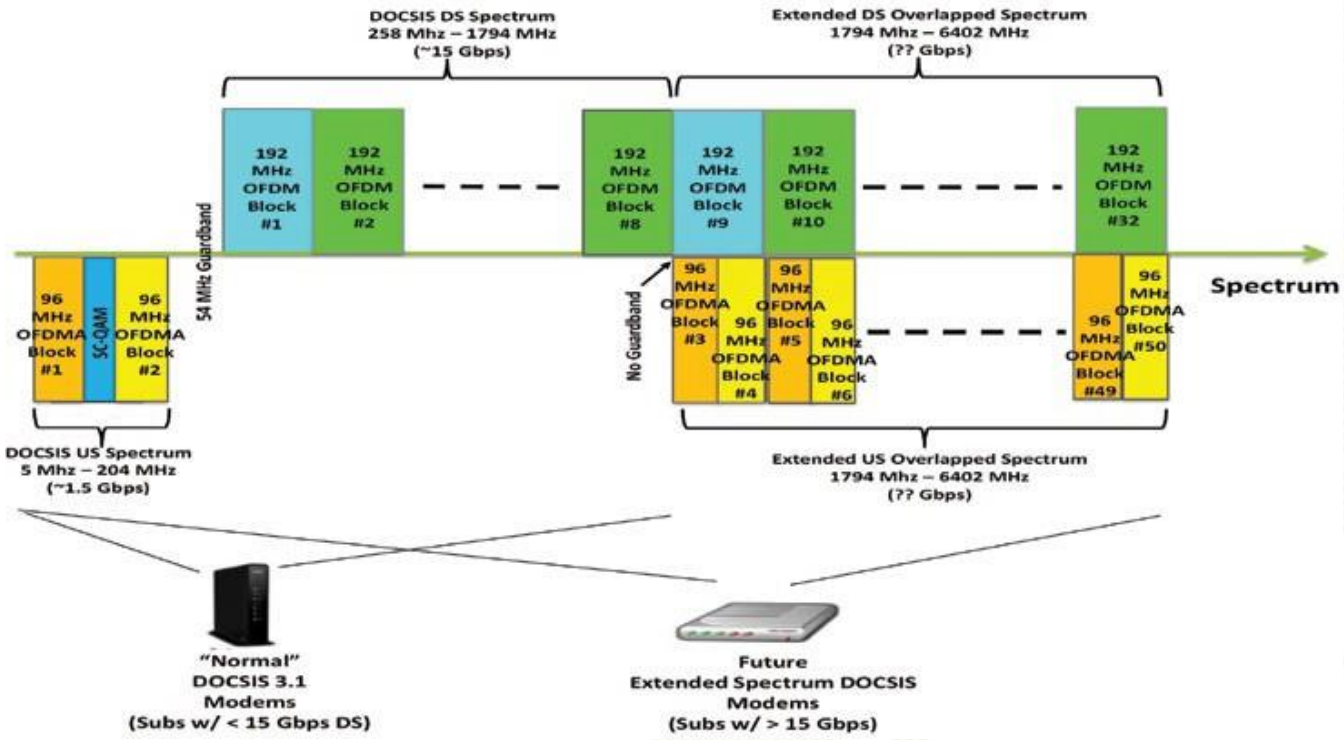
FULL DUPLEX / HALF DUPLEX FOR ESD SYSTEMS?

MSOs are continually being pushed by subscribers and competitors to increase their bandwidth capacities. In recent years, xPON service providers have begun challenging MSOs and are beginning to push MSOs to increase their DOCSIS® 3.1 Upstream bandwidth capacities. In response to these challenges, MSOs and their vendors are exploring many ways to provide more bandwidth capacity. As an example, there are currently very active studies under way to identify powerful, new techniques for operating the DOCSIS® 3.1 Upstream channels on the same frequencies as the DOCSIS® 3.1 Downstream channels. At least two different approaches for frequency spectrum sharing are being considered.

One of the frequency spectrum sharing approaches is based on Full Duplex operation, whereby the Upstream and Downstream signals occupy the same coax and the same portion of the spectrum at the same time. The signals essentially pass right through one another, and the receivers must detect and demodulate the arriving signal in the presence of the interference or "noise" from the signal propagating in the opposite direction. This requires the use of noise cancellation techniques in the CCAP Upstream Receiver. There must also be ways to circumvent noise at the modem Downstream Receiver, because non-ideal isolation in taps can permit energy from Upstream transmissions from a modem to couple into the Downstream spectrum on nearby, neighbor modems (see Figure 8). While solutions to these problems have some challenges and are still being studied, it is quite possible that some form of Full Duplex DOCSIS® [FDX] may be operating on DOCSIS® 3.1 systems in the next few years.

It should be noted that an extended spectrum DOCSIS® system based on FTTT will likely result in a point-to-point coaxial connection between the fibre node, which could be at the tap location, and the modem. Therefore, interference between neighboring modems in a Full Duplex DOCSIS® system is essentially eliminated. This may lead to many simplifications as well as performance enhancements within Full Duplex DOCSIS® systems because echo cancellation can be added at both ends. [5.Tom Cloonan, Ayham Al-Banna, Frank O'Keefe]

ASYMMETRICAL EXTENDED SPECTRUM DOCSIS® W/ SHARED SPECTRUM IN ~6.4 GHZ

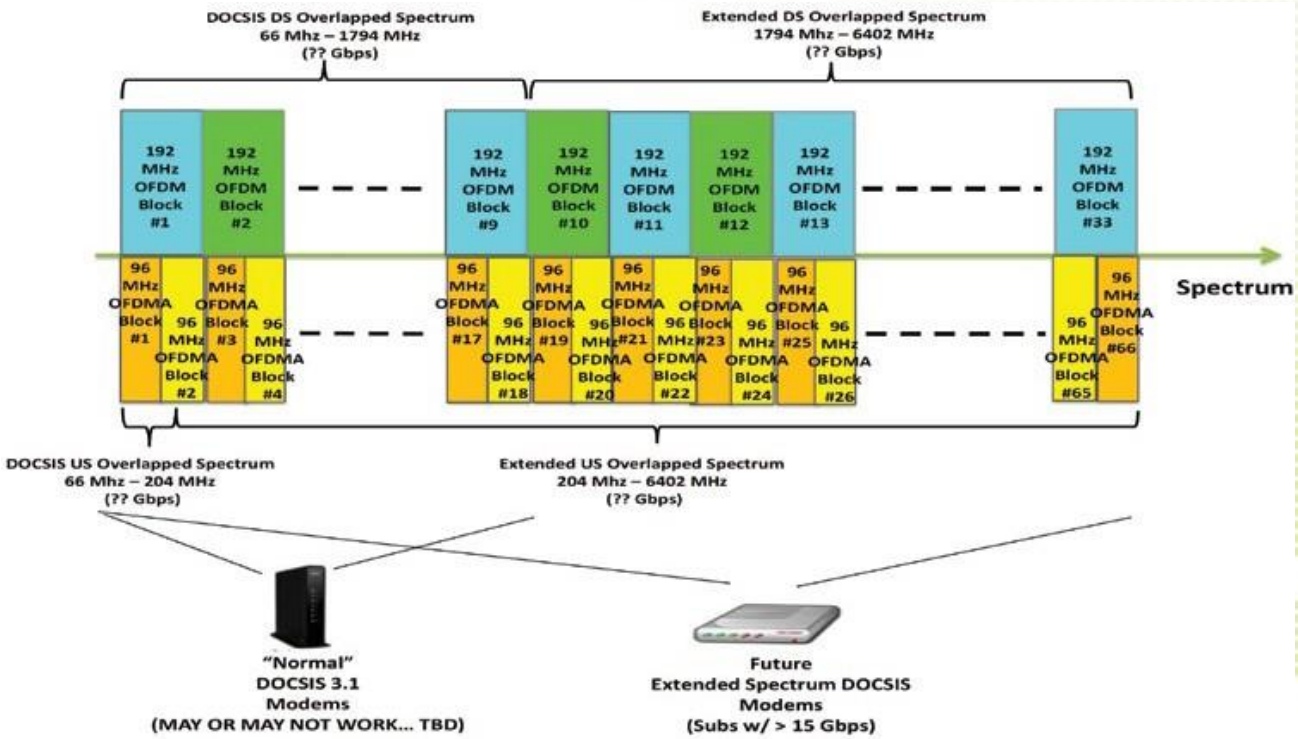


Asymmetrical Extended Spectrum DOCSIS® w/ Shared Spectrum in ~6.4 GHz

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge.14 "- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 22

SYMMETRICAL ESD WITH SHARED SPECTRUM



Symmetrical Extended Spectrum DOCSIS® w/ Shared Spectrum in ~6.4 GHz

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge 14 "- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 23

CAPACITY VS BANDWIDTH

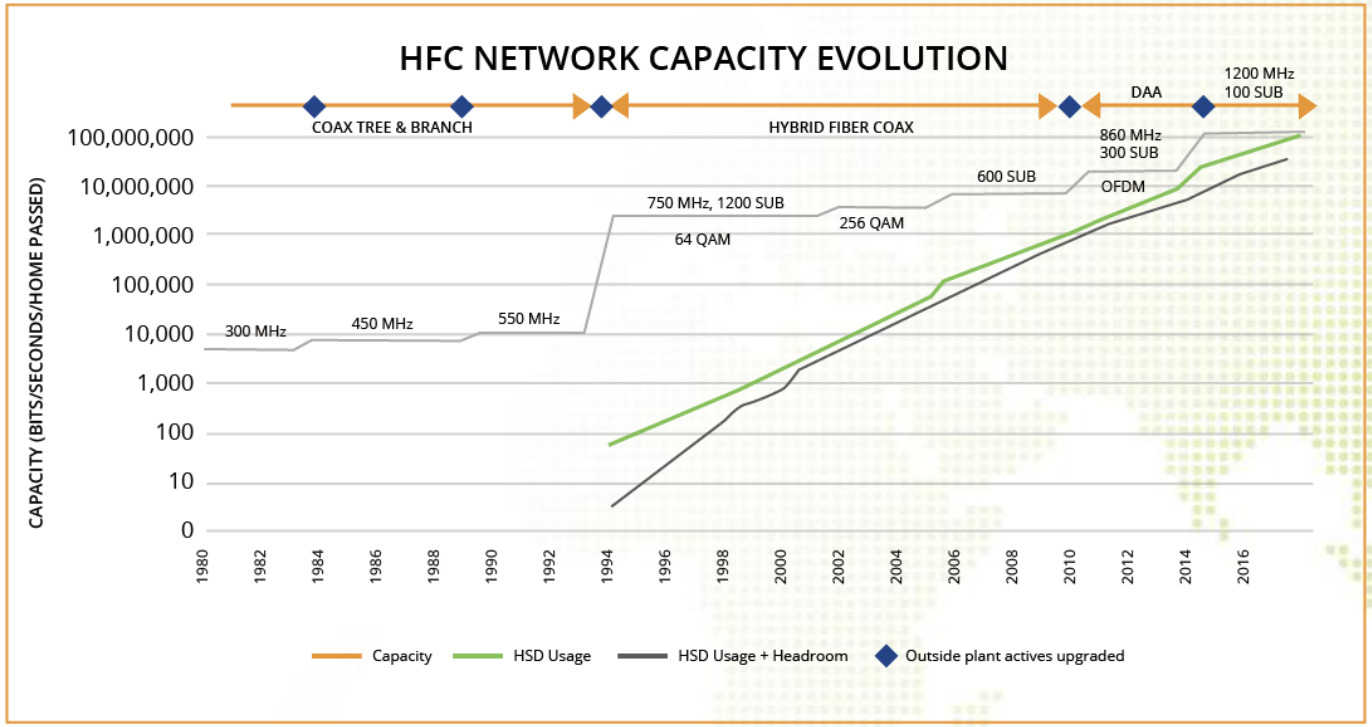
B (GHz)	S/N	SNR (dB)	C =*log2(1+S/N) (Gbps)
0.75	10,000	40.00	9.97
1.5	5,000	36.99	18.43
3	2,500	33.98	33.86
6	1,250	30.97	61.73
12	625	27.96	111.48
24	312.5	24.95	199.02

Capacity vs. Bandwidth

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge. 7 "- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 24

HFC NETWORK CAPACITY EVOLUTION



HFC Network Capacity Evolution - https://mktg-webtestext.arris.com/solutions/access-network-evolution-framework/

FIG. 25

OPERATIONAL CONSIDERATIONS

Before investing in any network upgrade projects or evolution, MSO's will need to consider not only current and projected traffic within each Service Group, but also key operational plant elements, like:

- **Head-end space/power**

Supporting growth in number of Service Groups given current space and power constraints in their head-ends.

- **Fibre utilization**

Supporting more wavelengths on a fibre by moving to digital optics? For example, 40-80 for digital optics vs. 16-32 for analog optics.

- **End-of-line signal quality**

Improving plant robustness and bandwidth capacity (better spectral density) using node-based RF generation.

- **Facility consolidation/FTTx alignment**

Reducing the number of headends with longer fibre runs with digital optics. Planning for both DOCSIS®® growth and FTTx plant migration.

- **Set-and-forget operational simplification**

Simplifying operational maintenance with digital optics instead of analog optics.

- **DOCSIS®® Management Systems (NMS)**

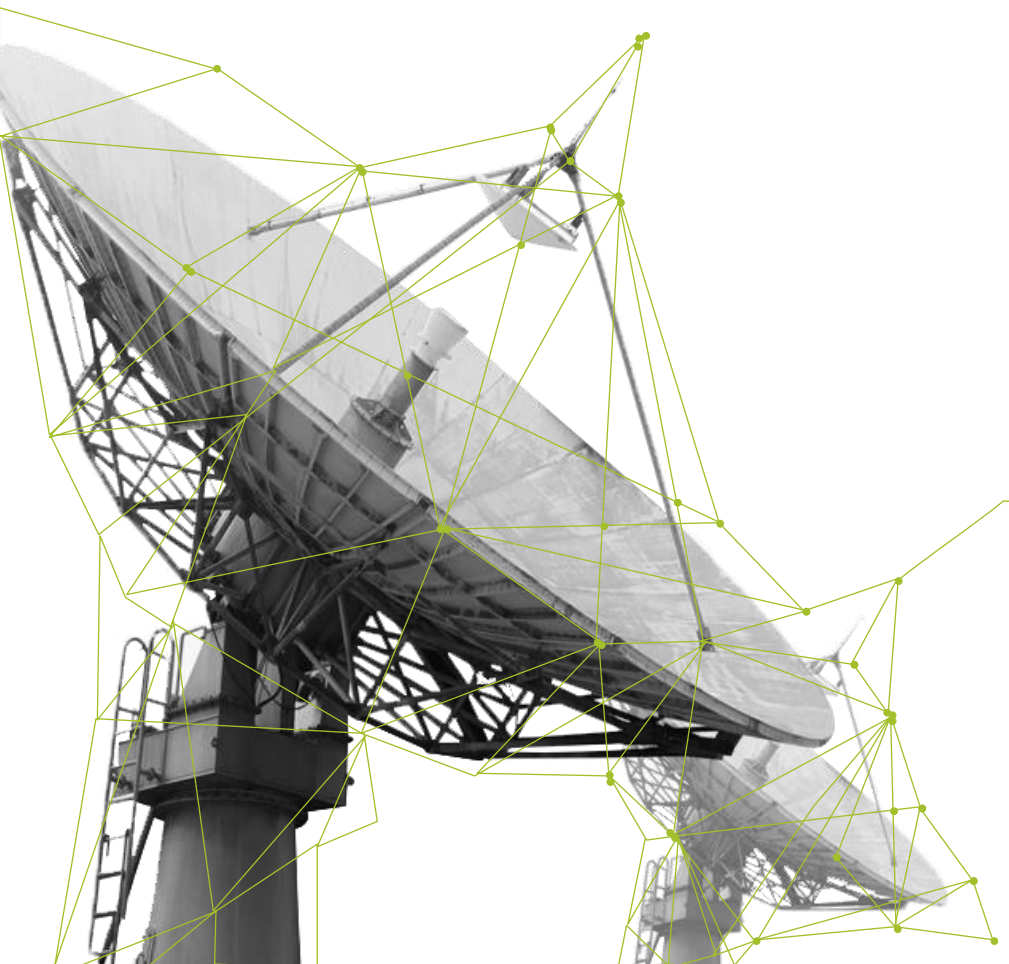
Note: Extended Spectrum DOCSIS® uses the same provisioning, configuration, and management systems as DOCSIS®, another key benefit is its ability to eliminate the unnecessary operational challenges that often accompany the introduction of a new technology.

DELIVERING BANDWIDTH FOR TODAY AND TOMORROW

In order to facilitate the shift to IP Video, Service Providers will have to efficiently achieve large scale migration of QAM-based distribution technologies, to IP-based distribution technologies. By standardizing on IP, not only can Service Providers simplify their infrastructures, they can also take advantage of the lower costs offered by web-based video services and CDNs as part of their video backbone distribution – all while meeting consumer demand for enhanced, multi-screen video.

The shift to IP Video also yields more flexibility when managing capacity for broadband data and gives Service Providers the ability to implement enhanced features like targeted advertising and blackout insertion, and encryption/digital rights management (DRM).

Simultaneously, the network needs to evolve in such a way that users of current platforms aren't left behind and continue to benefit from the introduction of new services. This means investment in IP solutions that can support existing QAM set-tops, while virtualizing the QAM infrastructure and enabling a smooth transition to an all-IP world.



8. GEO POLITICAL

COMMERCIAL OUTCOME VS NETWORK INVESTMENT

NBNco is required to realise a commercial outcome from its existing governmental MTM investment, whilst continuing to make the requisite further investments in the network to retain its customer base in an increasingly hostile competitive environment.

It also has a legacy requirement to support the transmission of FOXTEL over its cable network, and this legacy requirement still occupies significant Downstream bandwidth, which precludes the incumbent from fully utilising its broadband network, thereby enabling completion of its DOCSIS® 3.1 implementation.

As part of its MTM structured wholesale network, NBNco also operates FTTC (fibre to the curb) and FTTP (fibre to the premises) and a Fixed Wireless network. If the fibre penetrates too deeply into the HFC network….it will approach a FTTC topology and the question should be asked….

Hard-line fixed networks have always kept ahead of their wireless counterparts, but they are both useful in their own right, and fulfil market needs.

Wireless allows flexibility, hard-line allows raw throughput regardless of concentration of users or content. (through engineering configuration). The 10G Project will surely lead to an interesting convergence of technology in the near future as we migrate to an all IP world?

COMMERCIAL OUTCOME VS NETWORK INVESTMENT

THE CASE FOR CONTINUED INVESTMENT.....

It's no easy task to put a tag on the massive amount of capital that Telstra/Optus and now NBN co have poured into their networks since 1994.

Despite sizeable investments by MSO in America and Europe, the era of HFC expansion looked to be drawing to a close just a year or two ago.

The apparent shift in MSO priorities away from continued expansion of HFC spectrum created uncertainty on the supplier side of the ecosystem.

But within a year or two, industry consensus changed again. Many MSO are turning their attentions back to their decades-long investments in coaxial plant and now seem to be pursuing strategies that call for extending the spectrum ranges of their HFC networks to 1.8GHz or higher, as well as significantly extending the lifespans of their existing HFC plants.

Three factors contributed heavily to this turnaround. The first is an expanding embrace of Extended Spectrum DOCSIS® (ESD), a proposed extension to the long-serving DOCSIS® specification. By expanding the spectrum capacity of coaxial cable, starting with the 1.8GHz milestone mapped out by the recently published DOCSIS® 4.0 specification, and then moving to 3GHz or higher, cable operators have identified a path for accommodating bandwidth upgrades for at least the next decade or two.

SHINY OBJECTS

John Goddard

CEO/C-COR

“The human condition dictates that the potential to always be moving forward with technology is omnipresent”

It is important to realise that the materials and technologies that society views as progressive and ‘new’ today might already be ‘old news, or things’ in other circles”.

REFERENCES

1. *"The Path to 10G:2020 Update,INFORMED- BLOG by CableLabs, Jan 3, 2020 – Mariam Sorond*

2. *"The 2050 Project:Part 1," - WWW.ATX.COM*

3. *"Communications Day Article 27 August 2020 :The Father of DSL says FTTN net can be re-purposed as giant distributed 5G antennae net,"– Professor John Cioffi*

4. *"Communications Day Article 25 August 2020 :The argument for Upgrading NBN's HFC plant," – Dermot Cox, Consulter*

5. *"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond," - Tom Cloonan, Ayham Al-Banna, Frank O'Keefe. CommScope*
6. *"Post by Trevor Long on March 15, 2018."*

7. *"Upgrades on the cards as NBN Co secures extra $4billion from banks."-Fergus Hunter, The Sydney Morning Herald May 12, 2020*

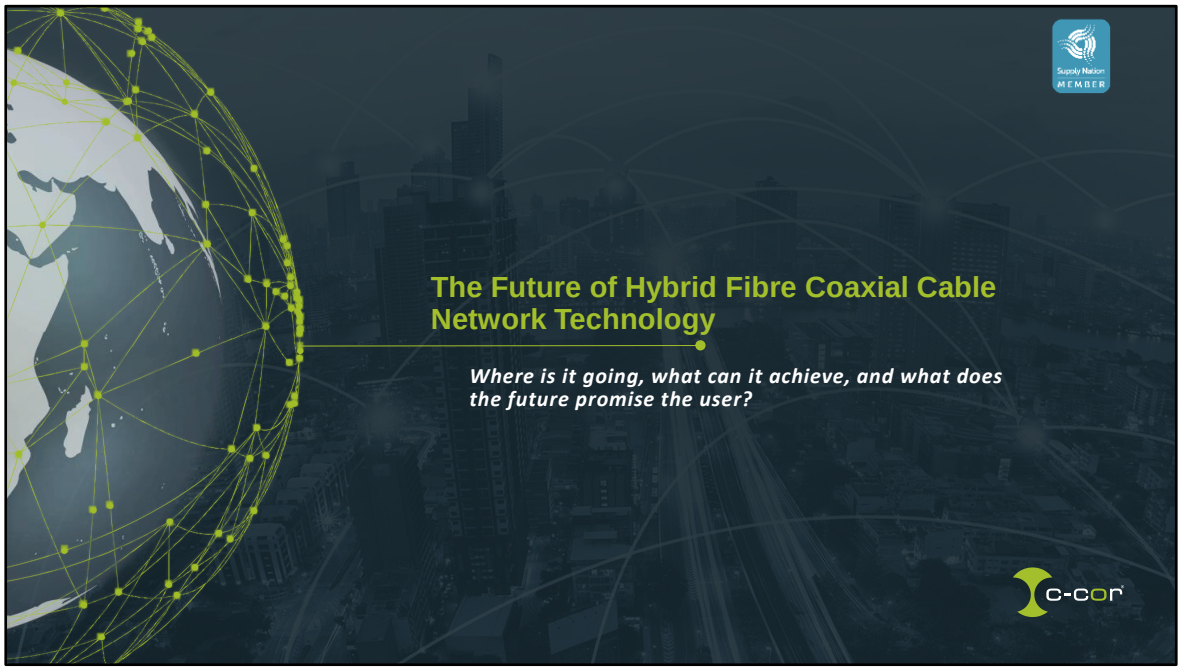
8. *"Comparing the DOCSIS® 3.1 and HFC Evolution to the FTTH Revolution," 2015 : Michael Emmendorfer - ARRIS*

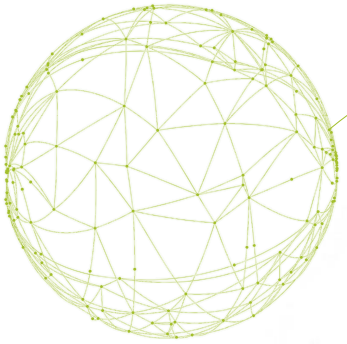
9. *"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks," April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.*

10. *HFC Network Capacity Evolution - https://mktg-webtestext.arris.com/solutions/access-network-evolution-framework/*

11. *Through to 2023 and Beyond - https://i.nextmedia.com.au/News/NBN_tech_options.png. IT News*

Thank you


Supply Nation
MEMBER
The Future of Hybrid Fibre Coaxial Cable Network Technology
Where is it going, what can it achieve, and what does the future promise the user?
c-cor



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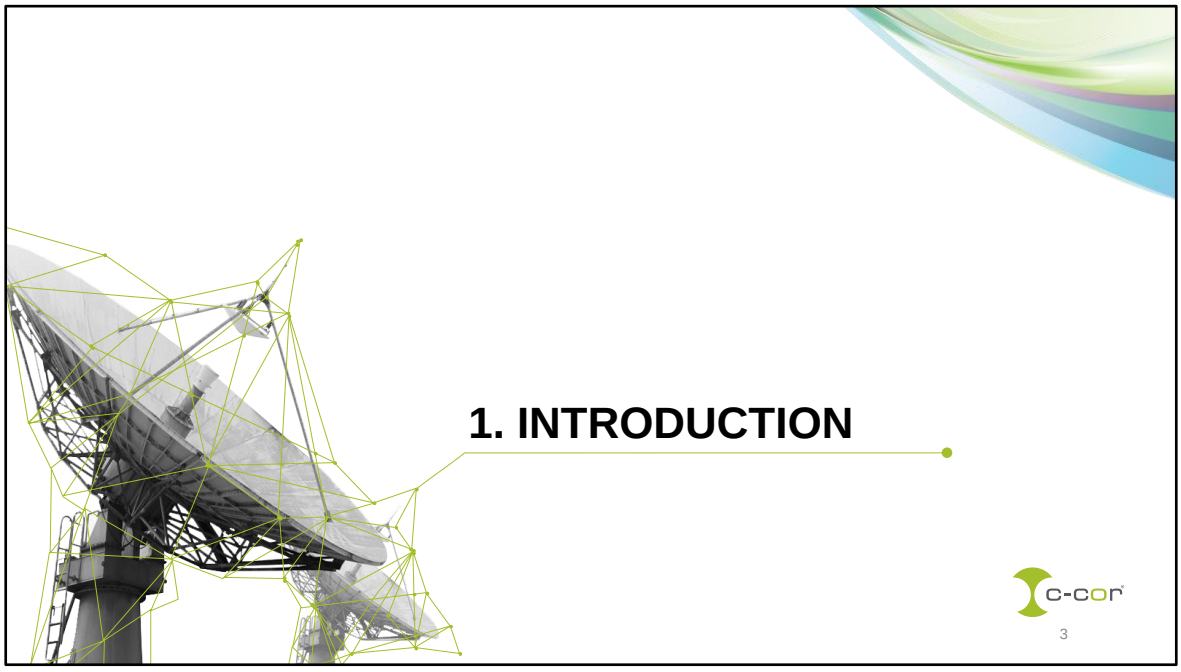
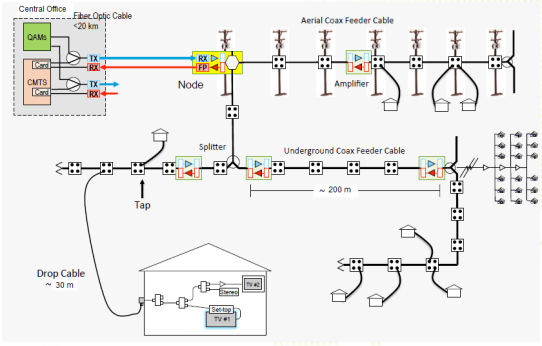


1. Introduction

The future of Hybrid Fibre Coax (HFC) is very important for Australia's National Broadband Network (NBN), with HFC passing about 2.4mn premises (representing @22% of the MTM total HH passed), and with about 2 mn HH with services connected today.
Today I will attempt to describe a potential future for the HFC, driven by the 'CableLabs' "10G project", leading to DOCSIS® 4.0. I will outline the stages in an NBN upgrade and some of the likely barriers to implementation. All this will be set in a context of ever changing end-user requirements, evolving network capabilities, and competitive technology landscape.

TYPICAL HFC PLANT



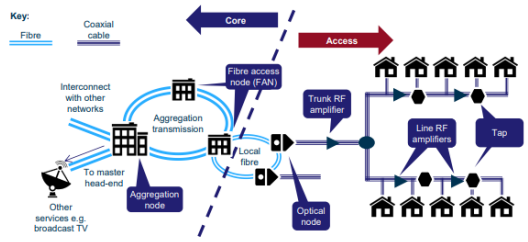
https://www.researchgate.net/figure/IPKOs-HFC-Network-Topology_fig2_308918787

FIG. 1

Describe this diagram noting the aerial vs underground split, central office configuration, TX/RX fibre connection to the node, through the coaxial feeder cable and coaxial drop to the home, where it is split to provide television and broadband data services.

https://www.researchgate.net/figure/IPKOs-HFC-Network-Topology_fig2_308918787

NETWORK OVERVIEW HFC PLANT

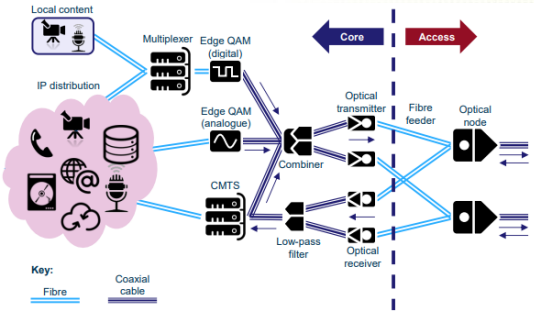


"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 80 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 2

Discuss the network architecture. Points of interconnect through to Metro Ring/ Aggregation transmission, local fibre , then to the node, coax and trunk amplifiers and line extenders through taps to the home.

COMBINED FAN AND AGGREGATION NODE

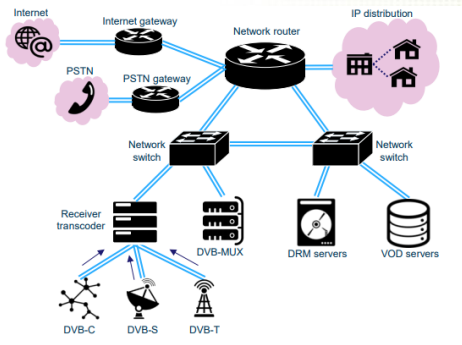


"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 81 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood, Analysys Mason Limited-Public Version.

FIG. 3

Discuss IP distribution to EdgeQAM and CMTS, addition of local content, through digital QAM, combined in the Core, and then split to optical nodes in the access network

MASTER HEADEND

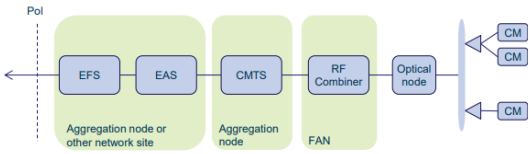


"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 82." April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 4

Discuss Internet, PSTN, and DVB/DVB-S and DVB-T links to Network Switches, plus the addition of DRM and VOD through network switch, linked to the Network Router to provide IP distribution to the Business/Home

INTERCONNECT WITH RSP'S

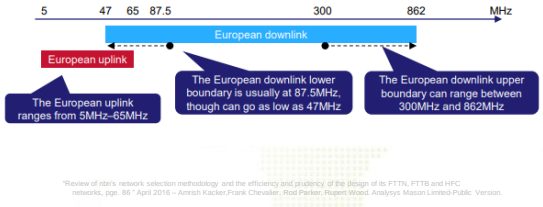


"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 83 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 5

This diagram describes how the 'carriage'network interconnects to the RSP's with the Point of Interconnect (POI) as the demarcation.

BANDPLAN RANGE FOR EUROPEAN CABLE SYSTEMS



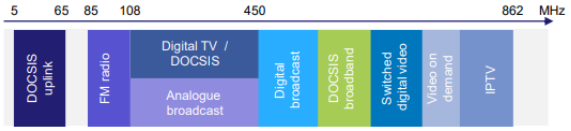
"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 86 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.

FIG. 6

(Analysys Mason 2016) The RF spectrum plan for all services is split into an uplink band operating at low frequencies and a (significantly wider) downlink band operating at higher frequencies, as shown in Figure 6. Different ranges are specified for DOCSIS® and EuroDOCSIS®,
with the Australian operators following the European approach. Given the typical customisation of various systems, the specific frequency plan used by individual operators may vary from one system (geographical region) to another, with the DOCSIS® specifications stating that
"the upper edge is implementation dependent but is typically in the range of 300 to 862MHz". Modern European systems typically operate with an uplink band of 5– 65MHz, and a downlink band of 87.5–862MHz.

The Telstra and Optus networks both operated in this uplink band range, but only up to 750/862MHz and 1GHz in the downlink direction

TYPICAL SPECTRUM PLAN UNDER EURODOCSIS® 3.0



"Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks, pge. 87 " April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood Analysys Mason Limited-Public Version.

FIG. 7

The above diagram depicts a typical network to 862MHzand beyond with a 65/85 split as per the Australian networks. Note 5-65MHZ band for Uplink and 85MHz – 862MHz and beyond occupies the Upstream.
Often 85-108 is used for FM radio, 108-450 is used for Digital TV/DOCSIS and Analog Broadcast chnls., 450-862MHz shows Digital broadcast, DOCSIS broadband, Switched Digital Video, VOD and IPTV.

COVID-19 HAS ACCELERATED THE TRENDS OF NETWORK USERS WORKING FROM HOME (OR ANYWHERE)

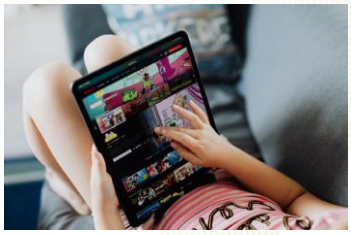


IMAGE 1

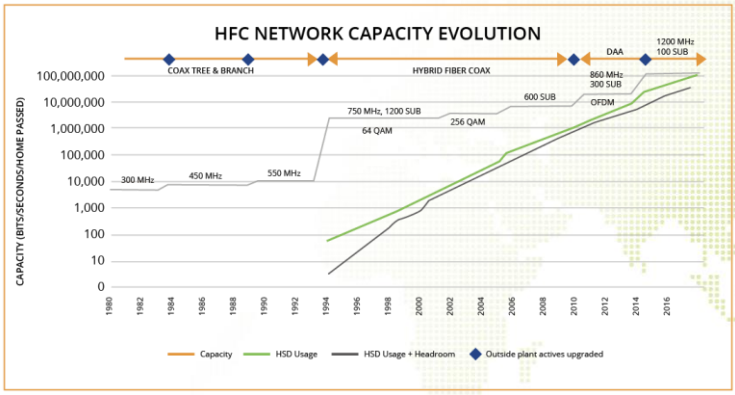
Today, the change in the way people consume content has put pressure on traditional television providers to reconsider the way they offer channels. Increasingly, customers are calling for unbundling and the opportunity to pay for only the channels they want.

At some point, people will make that decision of 'I can get everything I want (in streaming) and no longer need to have 180 channels of which they only watch 10. This decline of Cable TV 'per se' isn't a new story, but what has started to take hold has been a change in narrative inside the industry.

****The COVID crisis has accelerated the trends of network users working from home (or anywhere), of growth in*

peer-to-peer video services, and of end-users being creators of content as well as consumers of content. Note the growth of content "INFLUENCERS".
So it is being driven by content creators, but also by no. of connected devices within the home and when mobile.
Coupled to this is the introduction of 5G wireless. which adds further competitive capabilities to meet the needs of end-users.
While wireless broadband will become ubiquitous with 5G, the fixed-line access networks, including HFC, can "keep ahead" in delivering raw throughput, both downstream and upstream. .

HFC NETWORK CAPACITY EVOLUTION



HFC Network Capacity Evolution - https://mktg-webtestext.arris.com/solutions/access-network-evolution-framework/

FIG. 8

Over the years, with all the technological advances we have seen in cable, operators have continued to add more spectrum to their cable networks to meet increasing customer demands for bandwidth. These latest technological advances in DOCSIS® (to 3.1 in this example, and now 4.0), now provide us with the opportunity to rethink how we look at HFC network design. We recognize that cable has not only a long life left, but a long useful life ahead of it. In order to take advantage of the potential capacity increase that is available in DOCSIS® 4.0, we will need to evolve from our traditional outside plant designs.

HSD – High Speed Data

DOCSIS® 3.1 AUGMENTATIONS

In the near future, DOCSIS® 3.1 augmentations will expand the spectrum and the spectral efficiency of the HFC network to support (perhaps) ~10 Gbps Downstream bandwidth capacity and ~2 Gbps Upstream bandwidth capacity on a 1.2 GHz plant with a 204 MHz high-split. Discussions are now underway on the topics of Full-Duplex DOCSIS® that may permit even higher Upstream bandwidth capacities in the near future. Future DOCSIS® 3.1 expansions to 1.7 GHz may even permit the HFC network to even support ~15+ Gbps of Downstream bandwidth capacity.

This poses the following questions:-

- *Is the 15 Gbps bandwidth capacity of DOCSIS® 3.1 the last change that we will make to the HFC network?*
- *Is the bandwidth capacity offered by DOCSIS® 3.1 (in its current form) adequate for the long-haul into the future?*

EVOLUTION OF THE HFC NETWORK

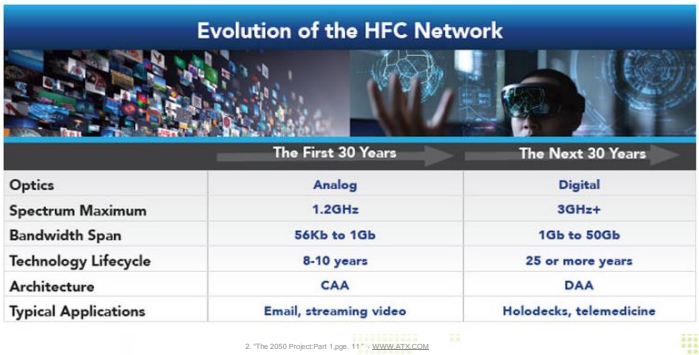
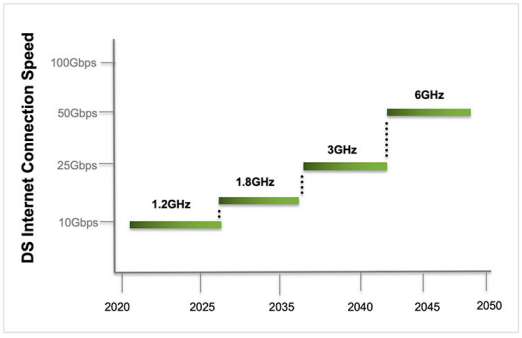


FIG. 9

Discuss the past vs the present and future in Optics, spectrum, lifecycle and architecture……..3GHz, 6GHz, 12GHz, to 25GHz and beyond is possible.

THE BILLBOARD BANDWIDTH QUESTION

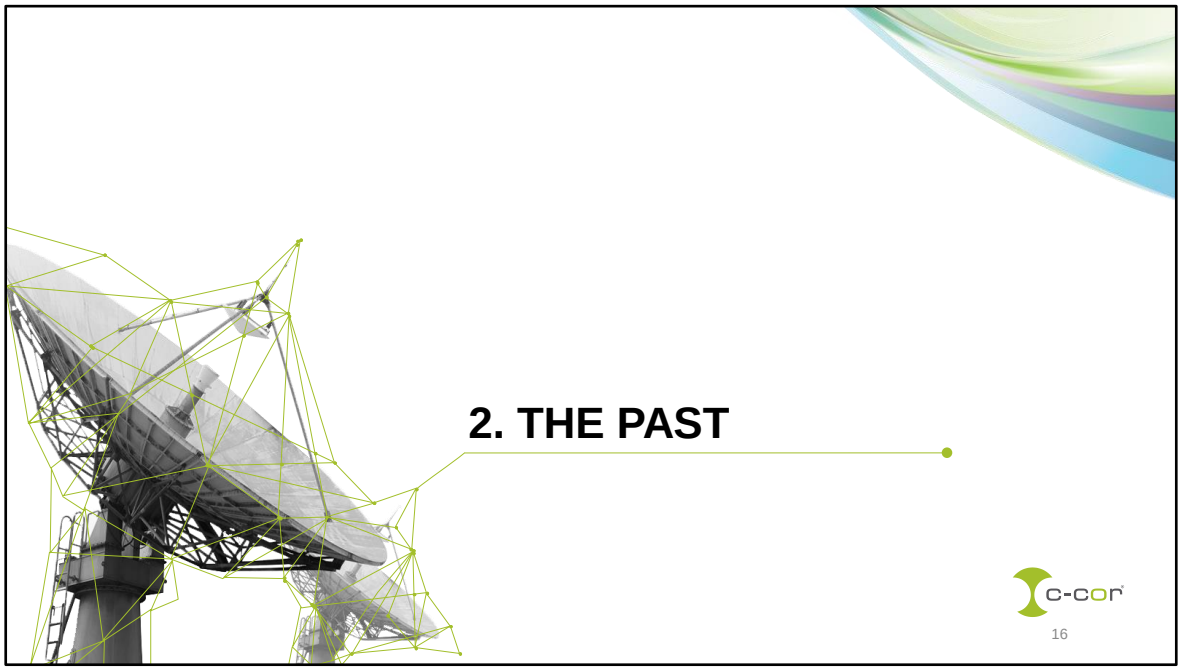


2. "The 2050 Project:Part 1,pge. 6 " WWW.ATX.COM

FIG. 10

(ATX Networks): Nielsen's Law of Internet Bandwidth, which charts bandwidth growth at about 50 percent annually, has been a fairly reliable predictor of so-called Billboard broadband rates (highest service tiers) for the past 30 years. But an array of technology, usage and architectural factors figure into Nielsen's projections, and many technologists predict that a 50% CAGR is unlikely to hold up over time……Supply and Demand: Incremental spectrum increases, anticipated with the adoption of Extended Spectrum DOCSIS®, over the next couple of decades will assist MSOs in leveraging their HFC networks to keep pace with

subscriber demand. Upgrade adoption timeframes are estimates and will differ from MSO to MSO.



In a presentation to this august body in 2014, I noted that the media and telecommunications industry was entering a period of rapid change, and that this change would be driven by consumers and competition,
and more importantly, that the consumers of the next decade will likely be those who have a desire to have any content made available anytime, anywhere and to any device.

IN 2014

John

C-COR

"The media and telecommunications industry is entering a period of rapid change. The change will be driven from consumers and competition.

The consumers of the next decade will likely be those whom have a desire to have any content made available anytime, anywhere and to any device ".

17

CONTENT ANYWHERE, ANYTIME, AND TO ANY DEVICE –

IMAGE 2

In 2014…..The programmers and telecommunication providers were planning how to meet this challenge. Consumers are not just recipients of content they have increasingly become creators and/or distributors of content.
We have seen in the last decade the use of peer-to-peer (P2P) and the sudden increase of YouTube and social networking, this has driven how telecommunication providers, like cable operators have become not only content distributors to the home but also increasingly "from" the home.
A key challenge the industry may face in the future is the transition from a largely broadcast service delivery network to a rapidly growing unicast delivery network.

THE TRANSITION FROM BROADCAST SERVICE DELIVERY TO UNICAST DELIVERY

IMAGE 3

In 2014, we observed that a key commercial challenge the Cable TV industry would face in the future was the transition from a largely broadcast service delivery network to a rapidly growing unicast delivery network. Today, the change in the way people consume content has put much pressure on traditional television providers to reconsider the way they offer channels.

We all know that the popular streaming channels such as Netflix, Amazon Prime, HBO, Hulu, and other digital channels such as Google, XBOX, xfinity , NatGeo, Disney etc.. are massive disruptive forces within the media and television industries, and are now challenging the entrenched "bouquet of channels" offerings provided

by traditional Cable providers such as Foxtel. Noting Foxtel also now has streaming services……

****** We have seen this at a local level, iiNet has seen increasing growth in its FETCH platform (similar to FOXTEL but originall more of a streaming service)*

NO LONGER A RECIPIENT OF CONTENT, BUT NOW A CREATOR

Creator / Distributor

IMAGE 4

20

I further noted that programmers, telecommunication and cable providers were planning how to meet this challenge in the future.
Consumers would no longer be just recipients of content, they would increasingly become creators and/or distributors of content.

VIDEO STREAMING IS THE NEW TV

Jamie

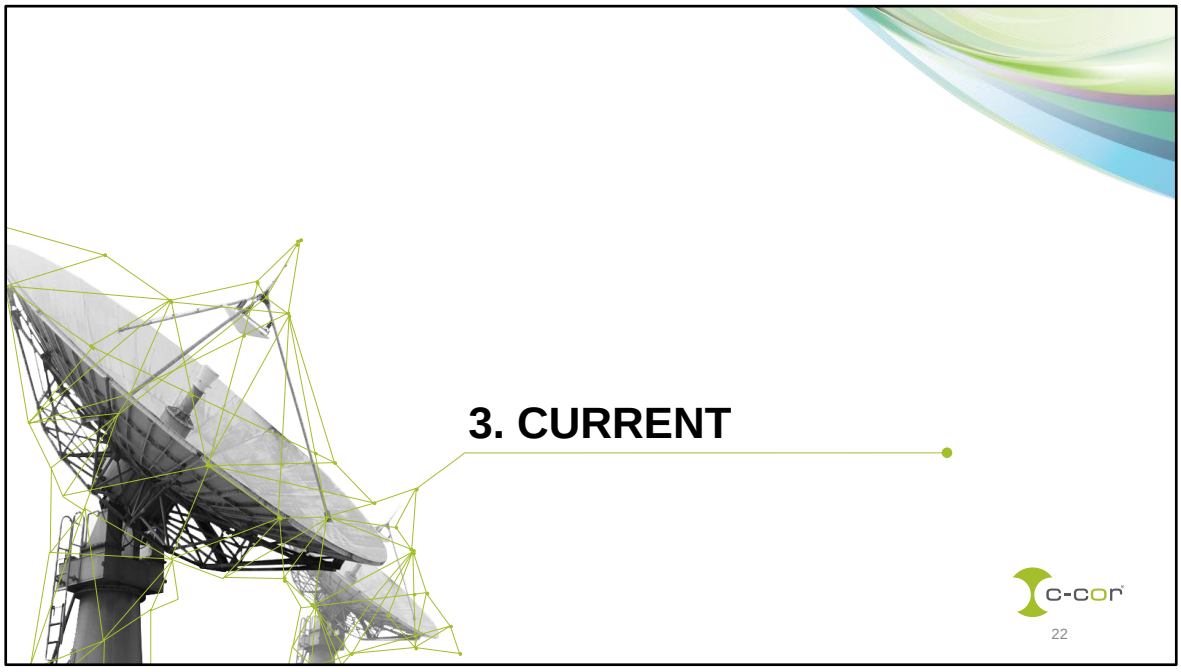
IMAGE 5

21

*****At a local level, there is surging demand for Channel Nine with its STAN and 9NOW video streaming services.*

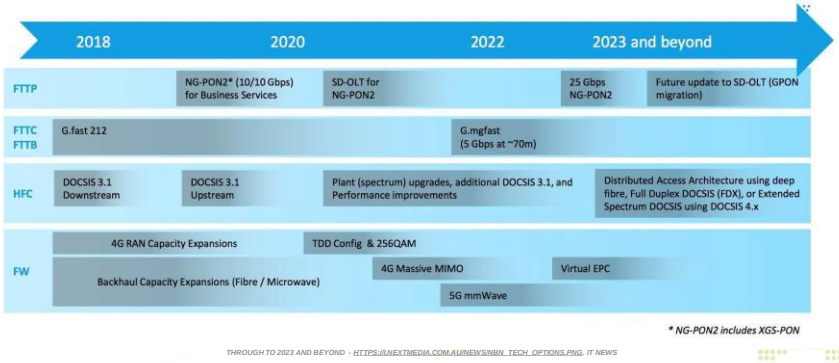
*********And a trend was emerging where the internet and other media had begun to 'not so' gradually replace the influence that television once had on society, with people mirroring what a network does on TV,*
by using their videos and making their money off of the advertising that is around them (banner ads) .

It is apparent to me that video streaming is the new TV as it follows roughly the same business model, but eliminates other costly variables at the same time.



The national broadband network (NBN) has transformed the local telco landscape through the promotion of the so called Multi Technology Mix (MTM) and the creation of a singular wholesale carrier broadband network.

FUTURE TECHNOLOGY OPTIONS - AN AUSTRALIAN PERSPECTIVE



THROUGH TO 2023 AND BEYOND - HTTPS://I.NEXTMEDIA.COM.AU/NEWS/NBN_TECH_OPTIONS.PNG, IT NEWS

FIG. 11

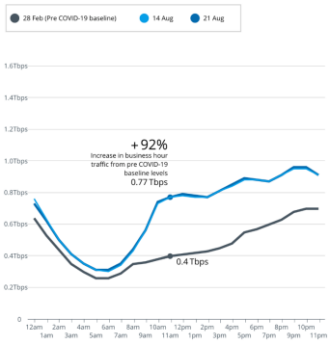
https://i.nextmedia.com.au/News/NBN_tech_options.png

IT News: ***Through to 2023 and beyond.*** *This figure is an older, publicly available document. In it, NBN Co has laid out a detailed roadmap and timeline of options to upgrade almost all last-mile access technologies barring fibre-to-the-node and satellite over the next five years.*

The roadmap shows where NBN Co's chief technology office's then thinking was around different upgrade paths, both immediately and for "2023 and beyond".

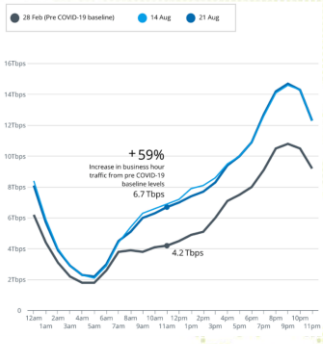
You will note that NBN Co clearly has HFC in its future roadmap, and it is my belief that the network has a solid future to 2030 and beyond with the DOCSIS®3.1 implementation, DAA, ESD, and DOCSIS® 4.0 implementation .

TRAFFIC SPIKES IN NETWORK USAGE



Upstream network usage

Upstream network usage, at 11am on Friday, 14 Aug increased 92% compared to Friday 28 Feb (Pre COVID-19 baseline



Downstream network usage

Network usage, at 11am on Friday, 21 August increased 59% compared to Friday 28 Feb (Pre COVID-19 baseline).

Source: https://www.nbnco.com.au/corporate-information/about-nbn-co/updates/dashboard-july-2020

FIG. 12

During the past six years, and more importantly during this current COVID-19 pandemic, we have seen that consumer demand has altered many aspects of the cable and broadband landscape, forcing some operators to quickly
augment their residential networks to stand up to spikes in traffic as consumers stayed at home. This behaviour has also been replicated overseas, where the demand for bandwidth over the cable network is higher than ever, as domestic and commercial usage increases daily, overseas operators are reporting increases of over 20% in downstream traffic and increases of at least 50% in the

upstream in the last few months.

PEER TO PEER (P2P)

IMAGE 6

The explosion in the use of peer-to-peer (P2P), and the sudden increase of YouTube and social networking (eg. Facebook and Tik Tok)……..

……..and the fact we are collaborating for business purposes as well as personal reasons and sharing not only "moments" but sharing significant time in REAL time expertise……eg. On demand Telemedicine, on demand consultancy etc..

has further driven the reality that telecommunication providers and cable operators have increasingly become not only content distributors to the home, but also increasingly, "from" the home, and home office.

25

The explosion in the use of peer-to-peer (P2P), and the sudden increase of YouTube and social networking (eg. Facebook and Tik Tok) has further driven the realisation of how telecommunication providers and cable operators have become not only content distributors to the home, but also increasingly, "from" the home.

VIRTUAL (ARTIST) COLLABORATIONS

Entertainment Industry

"Our inability to entertain in person, in groups, on stage, in arenas, or even to travel,

has led to the intelligent and thoughtful development of "Virtual" artist collaborations".

IMAGE 7

26

A further major development during this current period has been within the entertainment industry, whereby the inability to entertain in person, in groups, on stage, in arenas, or even to travel,
has led to the intelligent and thoughtful development of "Virtual" artist collaborations. What is even more interesting, is that these entertainment "artist collaborations" are now becoming a mainstream form of entertainment, and being widely televised on the broadcast networks.

YOUNGER VIEWERS – GEN Z

GenZ

IMAGE 8

I like to stream when I am not on YT, Social Media or gaming platforms…

I have no loyalty to cable whatsoever and no patience for commercials on TV

27

Young viewers, and children in particular don't think in terms of channels anymore, and the tremendous cratering of linear ratings at Nickelodeon, Disney Channel, and Cartoon Network bears that out. Viewers are still watching those 'networks' shows on streaming-when they're not on YouTube or gaming platforms, of course. But the fact that GenZ has no loyalty to cable whatsoever-and has no patience for commercials on TV-should sound plenty of alarm bells for anyone thinking about the cable business long term.

In the past we were a very assymetrical broadcast service. What we are seeing now is the beginning of an inflection point for more (up to full) symmetrical services to be offered in the future, and this is driving network architecture for fixed networks.

In the future, there will be a continuation of network architecture evolution in Cable networks worldwide, and locally within the NBN ecosystem, provided by both hardware and software innovation, but driven by customer demand and competition from technology in all domains……

The key advantage of fixed networks is that you don't have to buy spectrum to conduct your business. Spectrum is becoming a precious resource…….

Advances in signal processing in both fixed and mobile networks is continually being advanced and the two domains complement each other (some may call it convergence).

A LOOK AHEAD

IMAGE 9

The consumers of this next decade and beyond will continue to be those who have a desire to have any content made available anytime, anywhere and to any device, but at the same time, they will increasingly become creators and/or distributors of content. They will actively seek user enhancement and interface simplification capable of supporting a variety of experience including the enablement and intelligent and thoughtful development of "Virtual" artistic collaborations (in real time).

MULTI NETWORK UNIFICATION

IMAGE 10

Consumer demand has necessitated this move towards multi network unification within the same platform, and this has now been afforded by the rapid development of a Singular platform that will be capable of providing content discovery + consumption on the device of choice as per the so called "Smart TV" (or Gateway device).

AN IMMERSIVE FUTURE

IMAGE 11

Nobody, of course, can predict with any accuracy what the world will look like 10, 20 or 30 years from now. What we can count on, though, is that the communications infrastructure of the future will need to be highly responsive, incredibly fast and seamlessly interconnected. Given those demands, little doubt exists that denizens of our digital future will have any difficulty filling up a 25Gbps or even a 50Gbps pipe. MSOs will clearly need the incremental bandwidth boosts that injecting their HFC

plants with higher spectrum ranges will bring.

IMMERSIVE EDUCATION ?

IMAGE 12

https://www.youtube.com/watch?v=-kTeavB3IGg

More than a few futurists are now predicting hat the now-ubiquitous Smartphone will have outlived its purpose long before 2050, the Smartphone form factor falling into obsolescence in an environment of seamless connectivity and virtual reality.

Human-machine unification is also a major pillar of what is being called the Fourth Industrial Revolution, an AI-driven era that will eventually include a major displacement of the workforce by robots and other forms of automation.

SMART TV VARIANTS PAIR WITH VR EYEWEAR AND HEADSETS

IMAGE 13

To meet this demand, businesses such as Google, Apple, Netflix, Amazon and others are now all developing more powerful smart TVs, and the trend is likely to make the technology much more affordable for consumers.
It is envisaged that within the next few years, companies such as Facebook, Google and Microsoft who have all developed their Virtual Reality(VR) technologies, will have progressed the technology to the point where traditional television screens are likely to make way in part to variants that pair with VR eye-wear and headsets, and will be truly mainstream technology. Importantly, unlike traditional user interfaces,
***VR** places the user inside an experience. Instead of viewing a screen in front of them, users are immersed and able to interact with 3D worlds.*

VIRTUAL REALITY + AUGMENTED REALITY + MIXED REALITY

IMAGE 14

Virtual reality is a simulated experience that can be similar to or completely different from the real world. Applications of virtual reality can include entertainment, educational and business purposes.
Other, distinct types of VR style technology include augmented reality and mixed reality.

WIRELESS 5G/6G

IMAGE 15

Discuss the current massive investments by three major telco's in Australia in 5G technology.
- 4G massive mimo
- 5G mmwave technology

5G XHAUL

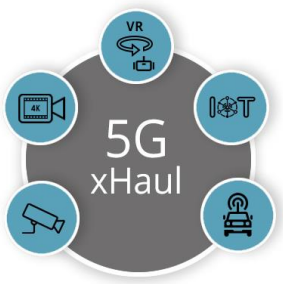


IMAGE 16

(RAD Technologies) : Low Latency Xhaul pipelines DOCSIS® B/W with less than 2ms latency

The main purpose of 5G-XHaul is to help ensure that every smartphone user has a reliable, uninterrupted and very high speed network connection. 5G-XHaul aims to find solutions to the growing demand for broadband connections.

To meet this demand cost-effective yet powerful networks must be developed and one of 5G-XHaul's main areas of focus will be on ensuring railway stations, airports and other transport hubs are connected to the core telecommunications network with dynamically adaptive communication.

WIFI 6 /6E AND 7

IMAGE 17

WIFI 6 is coming this year, with the promises of 9.6 Gbit / sec in unlicensed bands. This in itself is not a threat to cable as an end to end delivery ecosystem, but will nevertheless open up opportunities for fibre loop operators, for instance
Low Latency, High B/W, Machine to machine……..WiFi 7 will go to 6GHz

FTTC / FTTB - G.FAST 212

G.FAST IS A BASEBAND TECHNOLOGY WHICH USES TWISTED PAIR IN A FTTC / FTTB ARCHITECTURE –

AN EVOLUTION OF ADSL/VDSL TECHNOLOGY.

(ATX Networks): Twisted Pair base band technology FULL DUPLEX. DMT Modulation (discreet multi tone)

Operates in first 5-212MHZ of the legacy copper pair.

FIBER VS COAX

	Fiber	Coax/HFC
Capacity	√	X
Coverage	X	√
Convenience	X	√
Cost	X	√

****If MSOs could undergo a coax-to-glass transition with a snap of their fingers, they would do so in a second. Fiber is the undisputed option for new builds and instances where portions of the coax plant need to be replaced. The real question facing MSOs, is not if they should move to an all-fibre infrastructure, but how quickly.*

2. "The 2050 Project:Part 1, pge 8". - WWW.ATX.COM

FIG. 1

ATX Networks; This comparison chart of the two network types depicts that Fibre networks clearly lead in the capacity stakes. Multiple wavelengths, and seemingly endless capacity.
However, in the US, cable networks are ubiquitous, with connectivity virtually everywhere. On al other metrics of Coverage, Convenience and Cost, fibre networks will lose to Coax/HFC plant

CABLELABS INDUSTRY ROADMAP

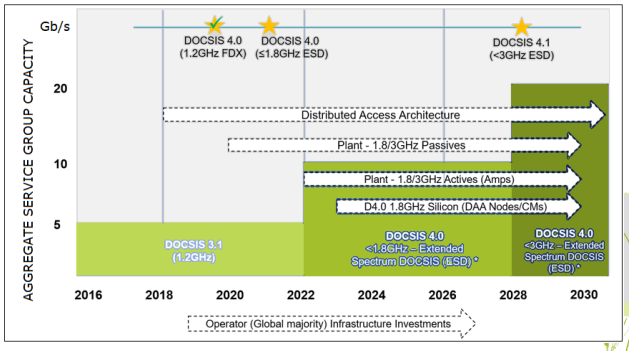
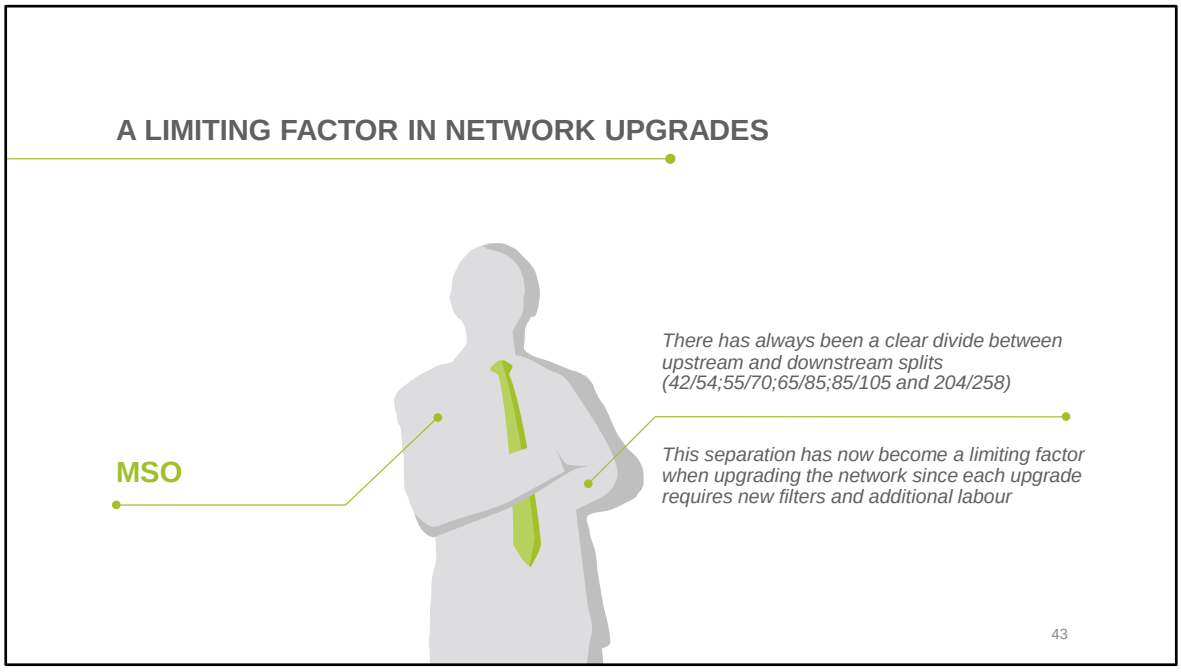


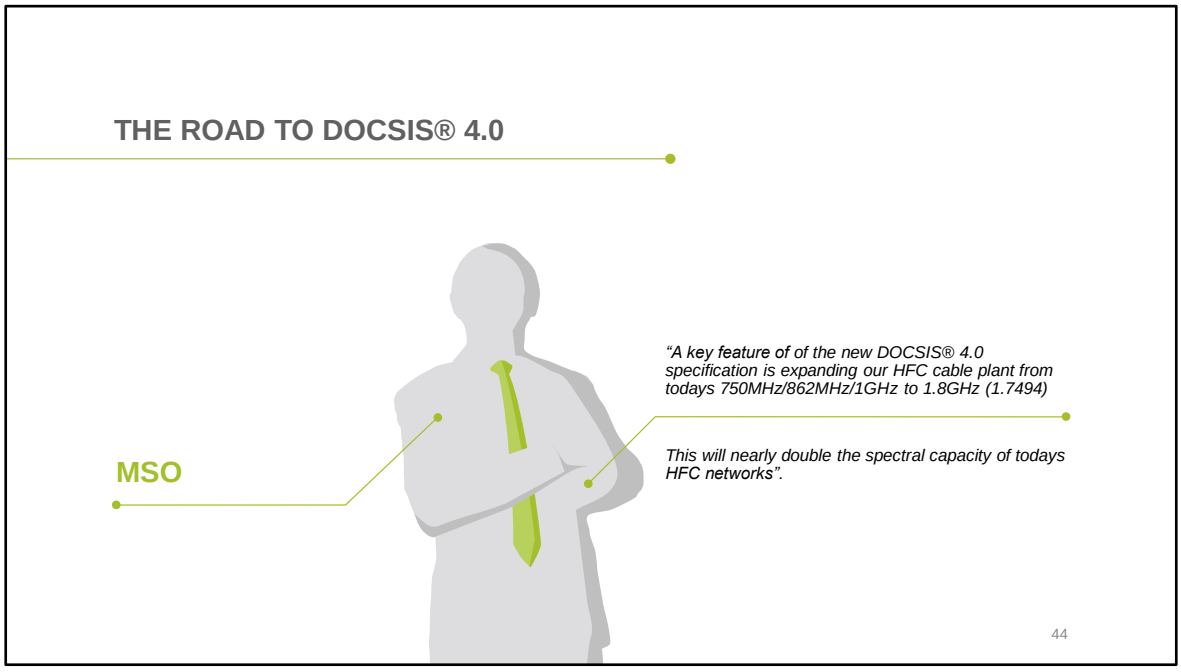
FIG. 15

There is renewed excitement in the cable market as RF technologies continue to evolve. *In the near future, DOCSIS® 3.1 augmentations will expand the spectrum and the spectral efficiency of the HFC* *creating a path for hybrid fibre/coax (HFC) systems to support 10 Gbps data transmission to support (perhaps) ~10 Gbps Downstream bandwidth capacity and ~2 Gbps Upstream bandwidth capacity on a 1.2 GHz plant with a 204 MHz high-split.*

10G will enable broadband connectivity and with higher connection speeds, lower latency (1-2ms), higher reliability and increased security……and it will also complement other access technologies….



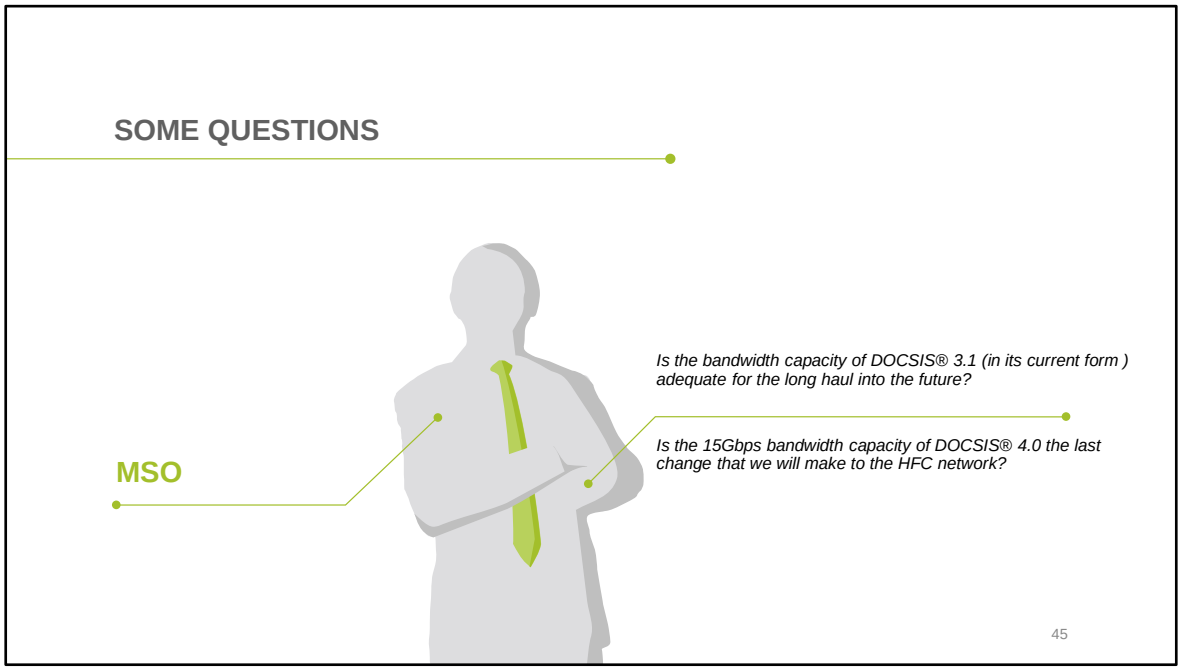
Historically, in HFC networks, there has always been a clear divide between upstream and downstream data splits (42/54; 55/70; 65/85, 85/105 and 204/258 etc. making it possible to upgrade signals in the existing network using by-pass filters and diplex filters in the active components.
But this separation has become a limiting factor when upgrading the network; each upgrade requires new filters and additional labour.



To answer these questions, we must explore the likely bandwidth requirements that may be placed on the HFC network over the next fifteen years. Voice and Video will always consume a reasonable percentage of the HFC spectrum.
Voice bandwidth requirements for small service groups of the future will be essentially negligible, but video bandwidth for those service groups will become quite large as Ultra-High Definition (UHD) feeds become more prevalent.

One of the key features of the new DOCSIS® 4.0 specification is expanding our HFC cable plant from todays 750MHz/860MHz/1GHz to 1.8GHz (1.79494)……and beyond in the future……..
This nearly doubles the spectral capacity of todays HFC networks.

But this UPSTREAM/DOWNSTREAM separation has become a limiting factor when upgrading the network; each NETWORK upgrade has required new filters and additional labour.



This then presents us with two questions:-

1. *Is the 15 Gbps bandwidth capacity of DOCSIS® 4.0 the last change that we will make to the HFC network?*
2. *Is the bandwidth capacity offered by DOCSIS® 3.1 (in its current form) adequate for the long-haul into the future?*

FULL-DUPLEX DOCSIS® & THE PROMISE OF MORE BANDWIDTH

- *Discussions underway on the topics of FULL-Duplex DOCSIS® suggest that it may permit even higher Upstream bandwidth capacities in the near future.*
- *Future DOCSIS® 4.0 expansions to 1.79494GHz may even permit the HFC network to support 15+ Gbps of Downstream bandwidth capacity.*
- *Fully realizing this potential, however, means making changes to the way the industry approaches architecture, which in turn requires new technology and techniques.*

Discussions are now underway on the topics of Full-Duplex DOCSIS® that may permit even higher Upstream bandwidth capacities in the near future. Future DOCSIS® 4.0 expansions to 1.79494 GHz may even permit the HFC network to even support ~15+ Gbps of Downstream bandwidth capacity.

Fully realizing this potential, however, means making changes to the way the industry approaches architecture, which in turn requires new technology and techniques. Here are some of the technology

challenges and considerations as HFC marches toward the 10 gigabit future.

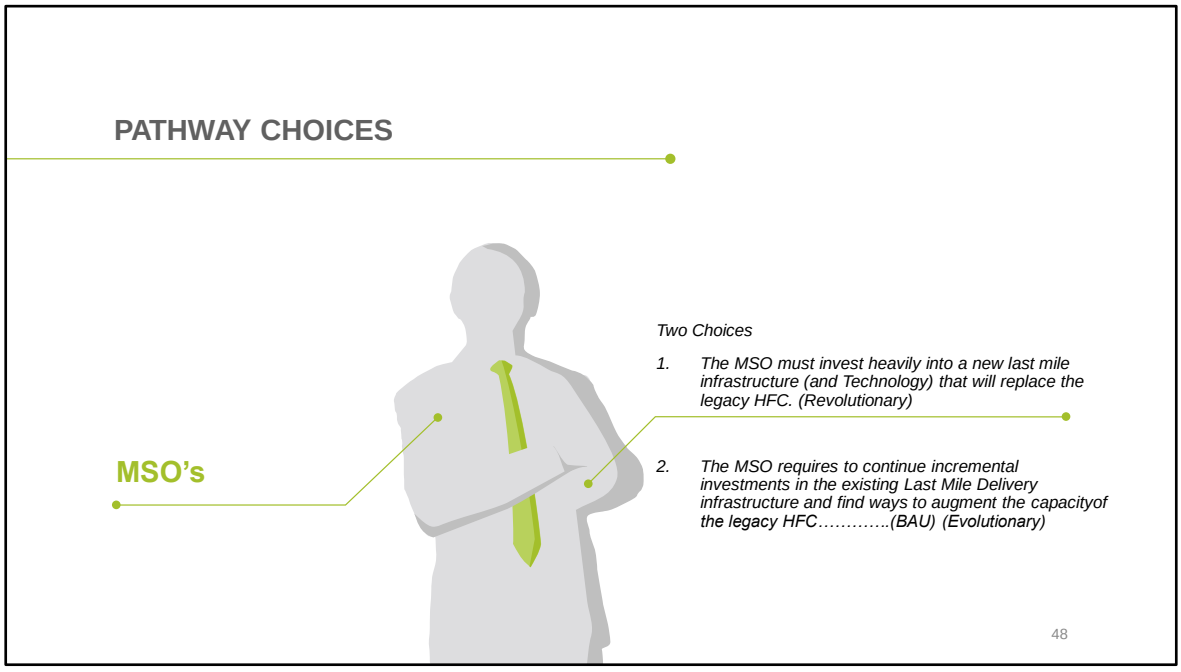
Possible Paths Supporting the Future Capacity Needs of Broadband

It is clear that the Cable Industry must plan for some changes if it is going to continue to support the growing Broadband capacity needs of subscribers into the deep future.

There are two possible paths/ directions that could be followed:-

The first (path) requires the MSO to invest heavily in a new Last-Mile Delivery infrastructure (and technology) that will ultimately replace the HFC network.

The second (path) would require the MSO to continue incremental investments (BAU) in the existing Last-Mile Delivery infrastructure, and to find new ways to augment the capacity of the legacy HFC network.



It is clear that we must plan for some changes if HFC is going to continue to support the growing Broadband capacity needs of subscribers into the deep future. There are two possible paths (directions) that could be followed.

The first path requires the MSO to invest heavily in a new Last-Mile Delivery infrastructure (and technology) that will ultimately replace the HFC network. FTTH systems are oftentimes assumed to be the desired end-state technology for Last-Mile Delivery systems, and that is probably a correct assumption. However, FTTH systems do tend to have one undesirable trait (for many MSOs). In particular, FTTH systems can be expensive to initially install and deploy. There are added complexities relating to craft expertise etc..

Estimates vary and depend on many conditions, but the cost of installing new fibre over the last 150' (50 metres) , to a typical home and equipping that home with a new ONU equipment can fall in the USD$500 – $1000 range. For many MSOs, the additional expense associated with adding a new FTTH connection to a home is not desirable and therefore other approaches must also be considered. A very promising approach is outlined in the following section.

The second path would require the MSO to continue 'incremental investments' in the

existing Last-Mile Delivery infrastructure, and to find new ways to augment the capacity of the legacy HFC network(s).

This is the "business-as-usual" approach that has been applied to the HFC network continuously for the past sixty years. It uses new technologies as they become available to continually push more and more bandwidth through the HFC system.

****** Over the years, with all the technological advances we have seen in cable, operators have never regretted adding more spectrum to their cable networks.***

LIMITATIONS TO TODAYS HFC DESIGNS

These latest technological advances in DOCSIS® 4.0, provide us with an opportunity to rethink how we look at HFC network design.

We recognise that cable has a long and useful life ahead of it.

MSO

49

****** Over the years, with all the technological advances we have seen in cable technology, operators have never regretted adding more spectrum to their cable networks. The addition of spectrum has always reaped rewards in the provision of additional bandwidthcapacity and the opportunity to provide more tiered video and data options to their subscribers/customers.*

These latest technological advances in DOCSIS® 4.0, provide us with the opportunity to rethink how we look at HFC network design. We recognize that cable has not only a long life left, but a long useful life ahead of it. In order to take advantage of the potential capacity increase that is available in DOCSIS® 4.0, we need to evolve from our traditional outside plant designs.

MOVE TO DOCSIS® 4.0 (THE PATH TO 10G PLATFORM)

"Is this a paradigm shift in the future of connectivity across platforms?"

"A fully realized connected network that enables all the different use cases and provides ubiquitous coverage through a seamless experience relying on multiple technologies and choices……"

The full move to DOCSIS® 4 ("10G" technology) would require a serious rework of the current HFC infrastructure. It would include DAA (Distributed Access Architecture) that would require deep full duplex fibre without amplification into the network and with MAC PHY node deployment at network edge points.

For DOCSIS® 4, at the CMTS level, only a DAA is to be supported-as proposed by the CableLabs® D4.0 working group. As the network moves to DOCSIS® 4.0 with Extended Spectrum to 1.8GHz using DAA , a benefit would be that the network can operate with existing D3.1

modems for customers that don't take higher speed tiers.

Mariam Sorond : The 10G Platform will enable broadband connectivity and with higher connection speeds, lower latency (1-2ms), higher reliability and increased security……and it will also complement other access technologies….

In 2014 I stated that "In the past, network operators that were the geo-incumbent broadband suppliers would feel little need to upgrade their offering purely based on customer demand,
unless there was a competitor who could supply a competitive broadband product to those customers."

Today, there are a number of drivers, that would prompt incumbent operators to continue to upgrade their networks……

CUSTOMER EXPERIENCE (QOE) VS QOS THRESHOLDS

"One of the technology strategy drivers for network operators today is the "Customer Experience", and the importance of alignment of network thresholds to the customer experience".

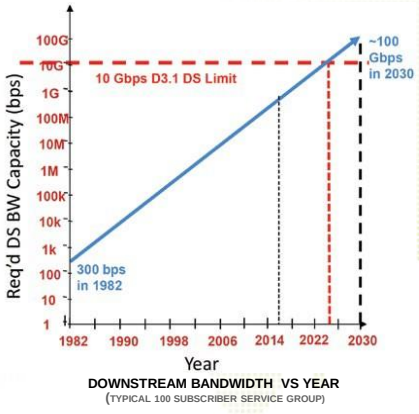
……."In the past, network operators that were the geo-incumbent broadband suppliers would feel little need to upgrade their offering purely based on customer demand, unless there was a competitor who could supply a competitive broadband product to those customers."

However, one of the technology strategy drivers for network operators today is the "Customer Experience", and the importance of alignment of network thresholds to the customer experience.

In Australia that alternative offering would most likely come from the Telcos and / or fibre loop operators in

“competition” with NBN, and would definitely include the incumbent mobile operators

EVER GROWING DEMAND FOR CAPACITY



DOWNSTREAM BANDWIDTH VS YEAR
(TYPICAL 100 SUBSCRIBER SERVICE GROUP)

"USING DOCSIS® TO MEET THE LARGER BW DEMAND OF THE 2020 DECADE AND BEYOND,PGE.4 "
- TOM CLOONAN, AYHAM AL-BANNA, FRANK O'KEEFE

FIG. 16

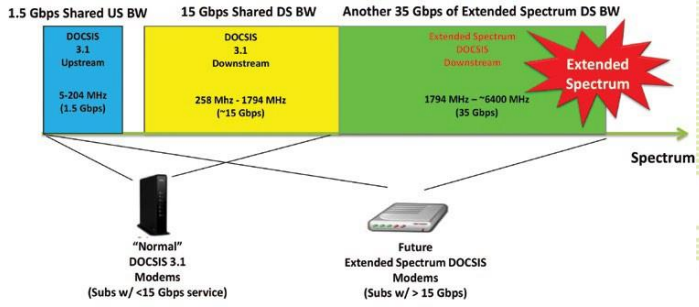
Broadband Services (with expected 50% annual growth rates) will also add an ever-growing demand of additional bandwidth capacity needs on top of that Video bandwidth capacity. If the Broadband growth rates are extrapolated into the future, the curve in Figure above is obtained (for a typical 100-subscriber Service Group of the future).

EXTENDED SPECTRUM DOCSIS®

Basic Idea Behind ESD

One approach focusing on the second path defined above is an approach known as "Extended Spectrum DOCSIS®." The idea is quite simple. Rather than change out the entire HFC plant for a new technology to increase their bandwidth capacity levels, MSOs can instead choose to continue to use the HFC plant by extending the spectrum that supports DOCSIS® 3.1 OFDM blocks beyond the 1.794 GHz limit that is specified in the DOCSIS® 3.1 specification today (see Figure below). The top frequency in the Extended Spectrum might be 3 GHz or 6 GHz or 12 GHz or higher. The actual top-end frequency and bandwidth capacity that can be utilized will undoubtedly be function of the manner in which the signals are delivered to the home. (Several different techniques will be outlined below).

ESD EXTENDED SPECTRUM DOCSIS®



Extended Spectrum DOCSIS® in Spectrum Offering ~50 Gbps in ~6 GHz

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge.6 "
- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 17

One approach focusing on the second path defined above is an approach known as "Extended Spectrum DOCSIS®." Rather than change out the entire HFC plant for a new technology to increase bandwidth capacity levels, MSOs can choose to continue to use the HFC plant by extending the spectrum that supports DOCSIS® 3.1 OFDM blocks beyond the 1.794 GHz limit that is specified in the DOCSIS® 3.1 specification today (see Figure 17). The top frequency in the Extended Spectrum might therefore be 3 GHz or 6 GHz or 12 GHz or higher. The actual top-end frequency and bandwidth capacity that can be utilized will undoubtedly be a function of the manner in which the signals are delivered to the home, taking into

consideration the optical cable and coaxial lengths.

HFC PLANT FOR ESD SYSTEMS

"Extended Spectrum DOCSIS® would require that several changes be made within the typical HFC network. Obviously, the HFC plant must have the ability to transmit and pass the higher-frequency signals from the head-end and across the fibre portion of the plant, through the fibre node, across the coaxial distribution leg of the plant, through amplifiers and taps, across the coaxial drop portion of the plant, through the coaxial in-home network, and to the modem in the home".

ESD AND HFC PLANT

There are many ways to pass these Extended Spectrum DOCSIS® signals through these elements. While it is theoretically possible for high-frequency amplifiers to be designed for passing these signals, the authors believe that most MSOs will likely prefer to wait until their HFC plants have been converted to Node+0 fibre Deep architectures before Extended Spectrum DOCSIS® will be considered as a desirable and feasible technology. (Note: This then eliminates the cost of upgrading many amplifiers, taps and passives to the higher frequencies required for the Extended Spectrum network).

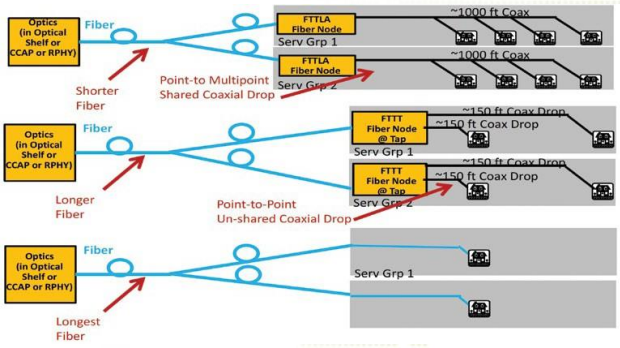
It seems fortuitous that many MSOs predict that they may be performing node splits down to Node+0 architectures before or around the same time that the 10-15 Gbps DOCSIS® 3.1 systems will be 'running out of gas'. (Note: It is also possible for MSOs to get to Node+0 architectures even if they keep their service groups large).

"As seen in Figure 17, it is expected that the required bandwidth capacity of a typical Service Group will exceed the available DOCSIS® 3.1 bandwidth capacity in the early-to mid-2020's. That is likely to be the time-frame when Extended Spectrum DOCSIS® may prove to be valuable. It is also the time-frame when Moore's Law silicon improvements will likely permit Extended Spectrum DOCSIS® systems to be deployed.

This 'perfect storm' of events implies that the early 2020's may be a perfect time to consider for initial deployments of Extended Spectrum DOCSIS® systems. Once an MSO begins to deploy Node+0 fibre Deep architecture designs, many variants of Extended Spectrum DOCSIS® systems could be envisioned." (5.Tom Cloonan, Ayham Al-Banna, Frank O'Keefe)

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, "- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FTTLA AND FTTT



Variants of HFC Plant Configurations for Extended Spectrum DOCSIS® Delivery

"Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge. 8 "
- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 18

In general, longer coaxial runs tend to lead to lower bandwidth capacities due to the higher attenuations (which increase as a function of both distance and frequency). However, longer fibre runs can also reduce bandwidth capacity due to dispersive and nonlinear noise effects (coupling energy between lambdas).
As mentioned earlier, the actual top-end frequency and bandwidth capacity that can be utilized will undoubtedly be a function of the manner in which the signals are delivered to the home, taking into consideration the optical cable and coaxial lengths.
A compromise will need to be found to maximize overall throughput for any given system.

DISTRIBUTED ACCESS ARCHITECTURE (DAA) FOR EXTENDED SPECTRUM DOCSIS® SYSTEMS

Extended Spectrum DOCSIS® offers a very flexible design. Due to this flexibility, it should be able to work very well with traditional Amplitude Modulated Optical signals being carried over the fibre portion of the HFC network. (Note: This is the type of solution that would be used within the RFoG solutions described in the previous section).

However, nonlinear optical effects resulting from interactions between lambdas on any lengthy wavelength-division multiplexed fibre may reduce the SNR values and reduce the throughput of the Extended Spectrum DOCSIS® system.

As a result, MSOs may alternatively choose to use Distributed Access Architectures (DAAs) to deliver the signals over the fibre portion of the HFC network. With DAAs, the fibre carries digital optics (Ethernet or xPON signals) from the head-end to the fibre Node, and the fibre Node produces the Amplitude Modulated signal that is ultimately transmitted over the coaxial portion of the HFC network. [5.Tom Cloonan, Ayham Al-Banna, Frank O'Keefe]

Two different variants of DAA architectures are being considered by MSOs—Remote PHY architectures and Remote MACPHY architectures.

Extended Spectrum DOCSIS® systems could be built using either of these DAA variants. In both cases, there are several benefits that would result. First, the use of a DAA approach would ensure that the SNR of the signals would not be significantly reduced by the nonlinearities within the fibre portion of the HFC network. Second, the use of DAA systems would help to reduce the power and space requirements in MSO head-ends when fibre deep solutions have created the need to support many small Service Groups. Third, the use of DAA systems (and digital optics) would also permit MSOs to place more lambdas on their wavelength-division multiplexed fibres. Fourth, the use of DAA systems (and digital optics) eliminates the presence of OBI within the digital fibre (since OBI only occurs in Amplitude Modulated optical systems).

Because of all of these reasons, MSOs who move to Extended Spectrum DOCSIS® will have the option to use either centralized or distributed access architectures.

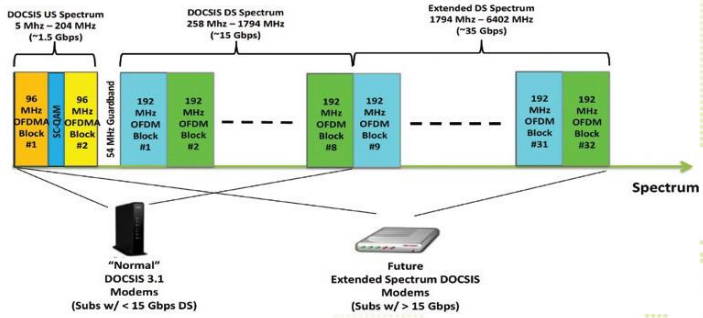
SPECTRUM CONSIDERATIONS FOR ESD DOCSIS® SYSTEMS

With Node+0 systems in place, MSO networks will be ready to carry Extended Spectrum DOCSIS® signals. The signals themselves may take the form of a stack of 192 MHz OFDM Downstream blocks (or a stack of 96 MHz OFDMA Upstream blocks) that inhabit regions of the spectrum beyond 1794 MHz.

The actual amount of spectrum that might be useable for this stack of OFDM/OFDMA blocks is a function of many parameters, including the signal launch power, the noise power injected on the fibre, the length of the fibre, the number of lambdas on the fibre, the wavelengths of the multiplexed lambdas, the noise power injected on the coax, the length of the coax, the attenuation of the coax, the amount of loss in taps, the amount of loss in splitters, modem receiver noise figure, etc.

Thus, depending on the design of the Node+0 system, different spectral widths will be allowed to carry Extended Spectrum DOCSIS® signals. Thus, it is possible that Extended Spectrum DOCSIS® systems of various flavors could be deployed differently by different MSOs. Some may choose to limit Extended Spectrum DOCSIS® operation to ~2.5 GHz. Others may choose to limit Extended Spectrum DOCSIS® operation to ~7 GHz. Still others may choose to push Extended Spectrum DOCSIS® operation all the way to ~10-25 GHz. In each case, the HFC plant must be appropriately conditioned (creating deeper fibre runs and shorter coaxial runs) to guarantee successful OFDM and OFDMA operation.

ASYMMETRICAL EXTENDED SPECTRUM DOCSIS® IN 2-BAND FDD SPECTRUM



Asymmetrical Extended Spectrum DOCSIS® in 2-band FDD Spectrum Offering

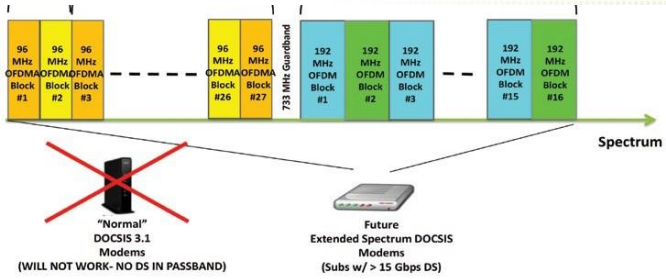
*Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge 11"- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 19

In this figure 96MHz OFDMA blocks are used in the Upstream…….192MHz OFDM blocks in the Downstream

As an example, consider a system with coaxial lengths that are short enough to permit ~6.4 GHz of spectrum to be passed. If an Extended Spectrum DOCSIS® system using ~6.4 GHz of spectrum were deployed, then it is possible that the system might place DOCSIS® Downstream spectrum from 258 MHz to 6402 MHz. This spectrum is large enough to hold thirty-two 192 MHz OFDM blocks. It is expected that channel bonding can be used across all of the 32 OFDM blocks. This is illustrated in Figure .
(Note: It is also possible that larger OFDM blocks could be defined in a future Extended Spectrum DOCSIS® specification. This would lead to the need for less OFDM blocks in the spectrum and less use of DOCSIS® channel bonding). The spectrum in Figure 19 is quite asymmetrical, with much more Downstream bandwidth capacity than Upstream bandwidth capacity. Note that the spectrum could also be divided in a different way……

SYMMETRICAL EXTENDED SPECTRUM DOCSIS® IN 2-BAND FDD SPECTRUM



Symmetrical Extended Spectrum DOCSIS® in 2-band FDD Spectrum
Offering ~20 Gbps x ~ 20 Gbps US in ~6.4 GHz

*Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond,pge. 11"- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 20

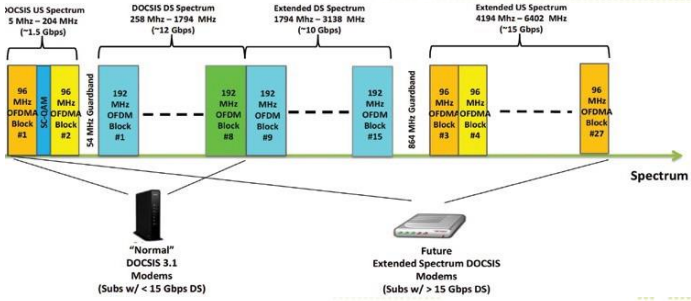
In this figure 96MHz OFDMA blocks are used in the Upstream…….192MHz OFDM blocks in the Downstream

Note that this particular configuration, shown in Figure above, will not permit DOCSIS® 3.1 modems to operate, because there is no Downstream spectrum in the "normal" Downstream portion of the spectrum where DOCSIS® 3.1 operates.

****A more symmetrical version of Extended Spectrum DOCSIS® could also be configured as shown in Figure 20 above where the Upstream spectrum ranges from 5 to 2597 MHz and the Downstream spectrum ranges from 3330 to 6402 MHz.*

This requires a larger 733 MHz guard band between the two directional spectra, and that leads to slightly lower overall bandwidth capacities. (Note: It may be possible to eliminate the guard bands in these designs, which is an ongoing topic still
under study within the Full-Duplex DOCSIS® effort [FDX] among MSOs, vendors and CableLabs).
Note that this particular configuration, shown in Figure 20, will not permit DOCSIS® 3.1 modems to operate, because there is no Downstream spectrum in the "normal" Downstream portion of the spectrum where DOCSIS® 3.1 operates.

SYMMETRICAL EXTENDED SPECTRUM DOCSIS® IN 3-BAND FDD SPECTRUM



Symmetrical Extended Spectrum DOCSIS® in 3-band FDD Spectrum
Offering ~22Gbps DS x ~16.5 Gbps US in 6.4 GHz

*Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge 12 "- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 21

In this figure 96MHz OFDMA blocks are used in the Upstream……..192MHz OFDM blocks in the Downstream

Another symmetrical version of Extended Spectrum DOCSIS® is shown in Figure21 above, This particular solution has the benefit of supporting symmetrical bandwidth capacities (with similar bandwidth capacities in the Upstream and Downstream directions) while also permitting DOCSIS® 3.1 modems to operate in the system. The disadvantage is that three bands (two Upstream bands and one Downstream band) must be utilized, and this leads to even more guard band being added to the system.

Furthermore, the limited upstream transmit power along with the high attenuation at the upper frequencies will cause the overall bandwidth capacity to be further reduced.

FULL DUPLEX / HALF DUPLEX FOR ESD SYSTEMS?

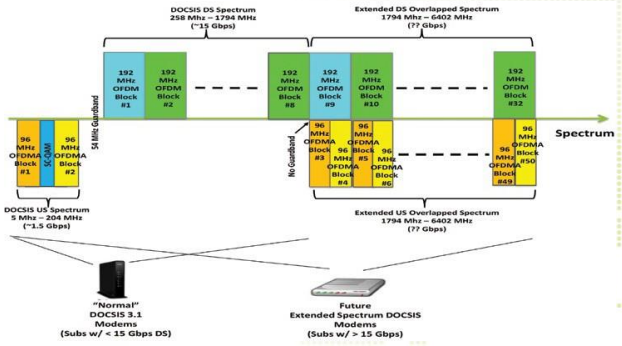
MSOs are continually being pushed by subscribers and competitors to increase their bandwidth capacities. In recent years, xPON service providers have begun challenging MSOs and are beginning to push MSOs to increase their DOCSIS® 3.1 Upstream bandwidth capacities. In response to these challenges, MSOs and their vendors are exploring many ways to provide more bandwidth capacity. As an example, there are currently very active studies under way to identify powerful, new techniques for operating the DOCSIS® 3.1 Upstream channels on the same frequencies as the DOCSIS® 3.1 Downstream channels. At least two different approaches for frequency spectrum sharing are being considered.

One of the frequency spectrum sharing approaches is based on Full Duplex operation, whereby the Upstream and Downstream signals occupy the same coax and the same portion of the spectrum at the same time. The signals essentially pass right through one another, and the receivers must detect and demodulate the arriving signal in the presence of the interference or "noise" from the signal propagating in the opposite direction. This requires the use of noise cancellation techniques in the CCAP Upstream Receiver. There must also be ways to circumvent noise at the modem Downstream Receiver, because non-ideal isolation in taps can permit energy from Upstream transmissions from a modem to couple into the Downstream spectrum on nearby, neighbor modems (see Figure 8). While solutions to these problems have some challenges and are still being studied, it is quite possible that some form of Full Duplex DOCSIS® [FDX] may be operating on DOCSIS® 3.1 systems in the next few years.

It should be noted that an extended spectrum DOCSIS® system based on FTTT will likely result in a point-to-point coaxial connection between the fibre node, which could be at the tap location, and the modem. Therefore, interference between neighboring modems in a Full Duplex DOCSIS® system is essentially eliminated. This may lead to many simplifications as well as performance enhancements within Full Duplex DOCSIS® systems because echo cancellation can be added at both ends. [5.Tom Cloonan, Ayham Al-Banna, Frank O'Keefe]

If either Full Duplex or Half Duplex DOCSIS® operation becomes a reality for DOCSIS® 3.1, it is likely that it would also be used in an Extended Spectrum DOCSIS® environment as well. Fortunately, the similarities between DOCSIS® 3.1 and Extended Spectrum DOCSIS® should permit any successful Full Duplex or Half Duplex approach to be easily applied to Extended Spectrum DOCSIS® systems.

ASYMMETRICAL EXTENDED SPECTRUM DOCSIS® W/ SHARED SPECTRUM IN ~6.4 GHZ



Asymmetrical Extended Spectrum DOCSIS® w/ Shared Spectrum in ~6.4 GHz

*Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge.14 - Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

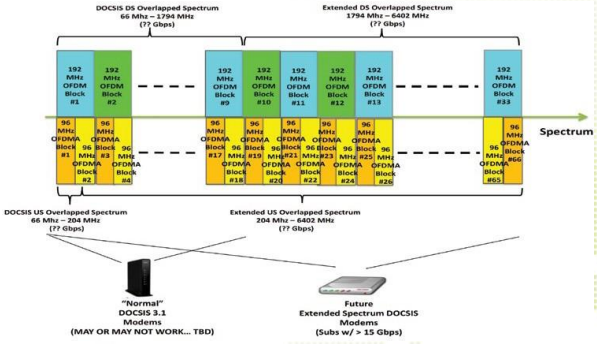
FIG. 22

The above example of a spectral map with overlapping Upstream OFDMA blocks and Downstream OFDM blocks shows a map that may permit DOCSIS® 3.1 modems to interoperate on the spectrum with Extended Spectrum DOCSIS® modems

****As an example, Figure above show examples of spectral maps with overlapping Upstream OFDMA blocks and Downstream OFDM blocks. The above map may permit DOCSIS® 3.1 modems to interoperate on the spectrum with Extended Spectrum DOCSIS® modems*

*****Extended Spectrum DOCSIS® uses the same provisioning, configuration, and management systems as DOCSIS®, another key benefit is its ability to eliminate the unnecessary operational challenges that oftentimes accompany the introduction of a new technology.*********

SYMMETRICAL ESD WITH SHARED SPECTRUM



Symmetrical Extended Spectrum DOCSIS® w/ Shared Spectrum in ~6.4 GHz

*Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge 14 *- Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 23

[5.*Tom Cloonan, Ayham Al-Banna, Frank O'Keefe*] *The above figure 23 shows an examples of a spectral map with overlapping Upstream OFDMA blocks and Downstream OFDM blocks shows a map that attempts to maximally fill the spectrum with Extended Spectrum DOCSIS® operation (which is likely to preclude the use of DOCSIS® 3.1 modems on the spectrum).*

*****Figure above shows a spectral maps with overlapping Upstream OFDMA blocks and Downstream OFDM blocks. This figure shows a map that attempts to maximally fill the spectrum with Extended Spectrum DOCSIS® operation. This spectral map can be used for either Full Duplex or Half Duplex operation.*

********Extended Spectrum DOCSIS® uses the same provisioning, configuration, and management systems as DOCSIS®, another key benefit is its ability to eliminate the unnecessary operational challenges that oftentimes accompany the introduction of a new technology.*************

CAPACITY VS BANDWIDTH

B (GHz)	S/N	SNR (dB)	C =*log2(1+S/N) (Gbps)
0.75	10,000	40.00	9.97
1.5	5,000	36.99	18.43
3	2,500	33.98	33.86
6	1,250	30.97	61.73
12	625	27.96	111.48
24	312.5	24.95	199.02

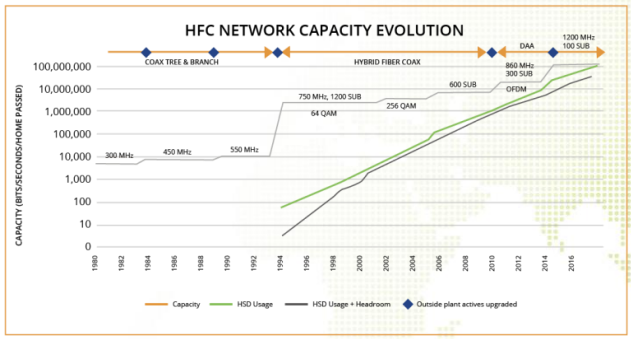
Capacity vs. Bandwidth

*Using DOCSIS® to Meet the Larger BW Demand of the 2020 Decade and Beyond, pge. 7 - Tom Cloonan, Ayham Al-Banna, Frank O'Keefe

FIG. 24

[5.*Tom Cloonan, Ayham Al-Banna, Frank O'Keefe]*

HFC NETWORK CAPACITY EVOLUTION



HFC Network Capacity Evolution - https://mktg-webtestext.arris.com/solutions/access-network-evolution-framework/

FIG. 25

Increased household penetration and 40-50% CAGR in broadband traffic will impact the ability of today's HFC networks to support growth over next 10 years. Even with network upgrades, the model predicts there will be little to no room for QAM video on the network at the end of the forecast period.

OPERATIONAL CONSIDERATIONS

Before investing in any network upgrade projects or evolution, MSO's will need to consider not only current and projected traffic within each Service Group, but also key operational plant elements, like:

- **Head-end space/power**
Supporting growth in number of Service Groups given current space and power constraints in their head-ends.
- **Fibre utilization**
Supporting more wavelengths on a fibre by moving to digital optics? For example, 40-80 for digital optics vs. 16-32 for analog optics.
- **End-of-line signal quality**
Improving plant robustness and bandwidth capacity (better spectral density) using node-based RF generation.
- **Facility consolidation/FTTx alignment**
Reducing the number of headends with longer fibre runs with digital optics. Planning for both DOCSIS®* growth and FTTx plant migration.
- **Set-and-forget operational simplification**
Simplifying operational maintenance with digital optics instead of analog optics.
- **DOCSIS®* Management Systems (NMS)**
Note: Extended Spectrum DOCSIS® uses the same provisioning, configuration, and management systems as DOCSIS®, another key benefit is its ability to eliminate the unnecessary operational challenges that often accompany the introduction of a new technology.

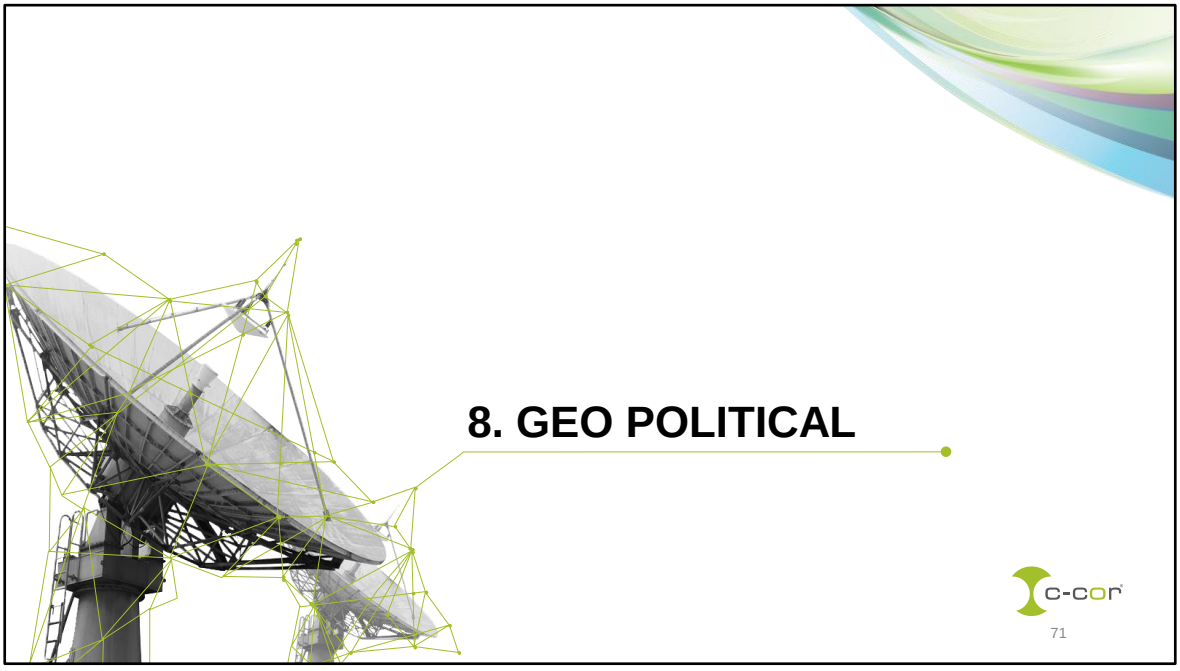
Extended Spectrum DOCSIS®® uses the same provisioning, configuration, and management systems as DOCSIS®. Another key benefit is its ability to eliminate the unnecessary operational challenges that oftentimes accompany the introduction of a new technology. Note the Technology Domain enablement for future capabilities (AI, Streaming, Analytics etc.

DELIVERING BANDWIDTH FOR TODAY AND TOMORROW

In order to facilitate the shift to IP Video, Service Providers will have to efficiently achieve large scale migration of QAM-based distribution technologies, to IP-based distribution technologies. By standardizing on IP, not only can Service Providers simplify their infrastructures, they can also take advantage of the lower costs offered by web-based video services and CDNs as part of their video backbone distribution – all while meeting consumer demand for enhanced, multi-screen video.

The shift to IP Video also yields more flexibility when managing capacity for broadband data and gives Service Providers the ability to implement enhanced features like targeted advertising and blackout insertion, and encryption/digital rights management (DRM).

Simultaneously, the network needs to evolve in such a way that users of current platforms aren't left behind and continue to benefit from the introduction of new services. This means investment in IP solutions that can support existing QAM set-tops, while virtualizing the QAM infrastructure and enabling a smooth transition to an all-IP world.

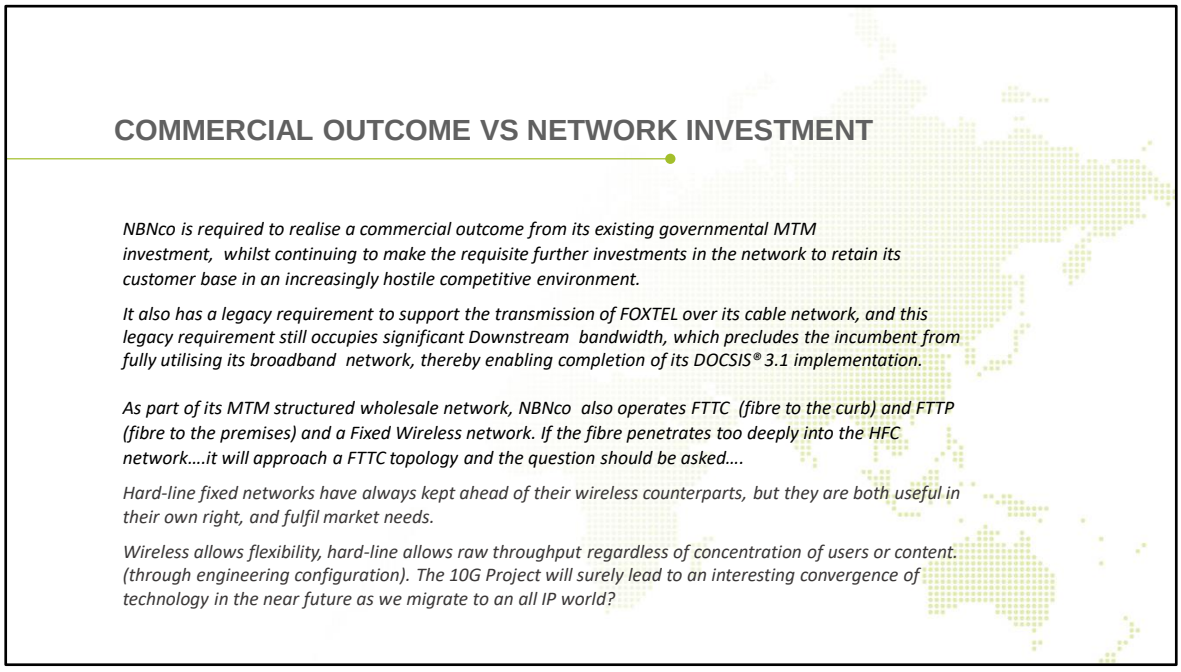


A question of funding

In May, NBN Co announced it had secured a total $6.1 Billion in debt finance from banks, $2 Billion of which falls into the existing $51 Billion rollout budget.

The Government said the company's decision to secure an additional $4.1 Billion was sensible and gave it flexibility to invest.

Subject to ministerial approval, an amount of $2.6 Billion would be made available for "strategic investments" which could include bringing forward potential network upgrades.



NBNco is burdened with the requirement to realise a commercial outcome from its existing governmental MTM investment, whilst making the requisite further investments in the network to retain its customer base in an increasingly (hostile) competitive environment.

It has also been burdened with a legacy requirement to support the transmission of FOXTEL over its cable network, and this legacy requirement still occupies significant Downstream bandwidth, which

precludes the incumbent from fully utilising its broadband network,
thereby enabling completion of its DOCSIS® 3.1 implementation. It should be noted that as part of its MTM structured wholesale network, NBNco also operates FTTC (fibre to the curb) and FTTP (fibre to the premises) and a selected Fixed Wireless network.
If the fibre penetrates too deeply into the HFC network…it is approaching a FTTC topology and and the question has to be asked……..
Hard-line fixed networks have always kept ahead of their wireless counterparts, but they are both useful in their own right, and fulfil market needs.

Wireless allows flexibility, hard-line allows raw throughput regardless of concentration of users or content. (through engineering configuration).

COMMERCIAL OUTCOME VS NETWORK INVESTMENT

THE CASE FOR CONTINUED INVESTMENT…..

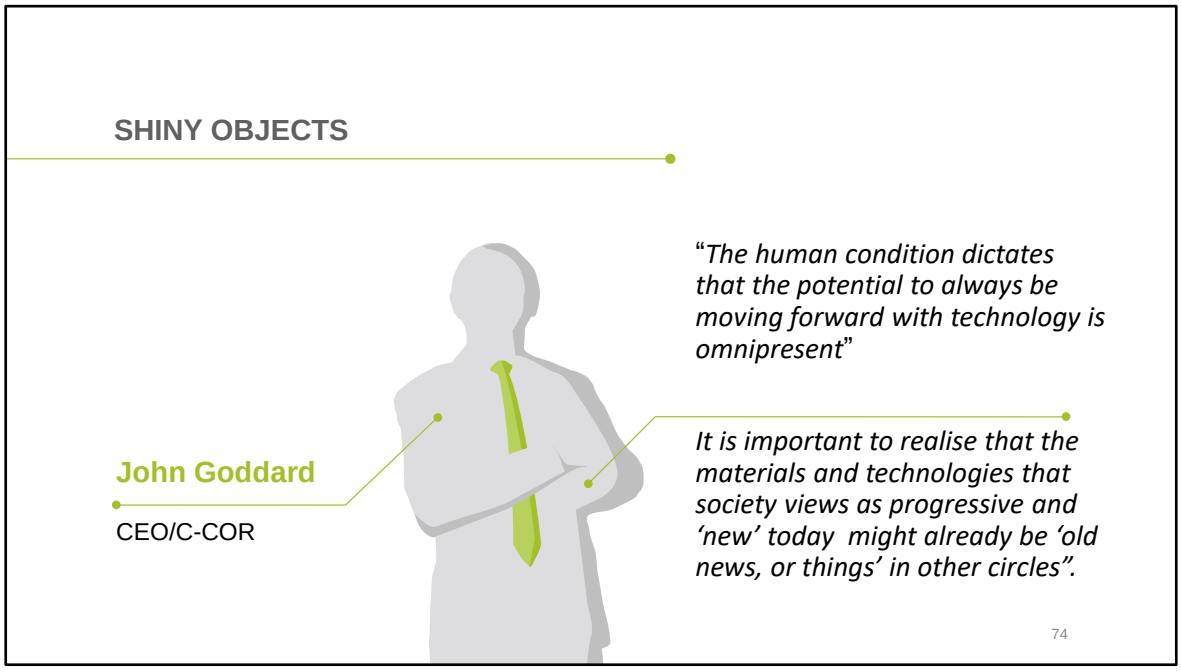
It's no easy task to put a tag on the massive amount of capital that Telstra/Optus and now NBN co have poured into their networks since 1994.

Despite sizeable investments by MSO in America and Europe, the era of HFC expansion looked to be drawing to a close just a year or two ago.

The apparent shift in MSO priorities away from continued expansion of HFC spectrum created uncertainty on the supplier side of the ecosystem.

But within a year or two, industry consensus changed again. Many MSO are turning their attentions back to their decades-long investments in coaxial plant and now seem to be pursuing strategies that call for extending the spectrum ranges of their HFC networks to 1.8GHz or higher, as well as significantly extending the lifespans of their existing HFC plants.

Three factors contributed heavily to this turnaround. The first is an expanding embrace of Extended Spectrum DOCSIS® (ESD), a proposed extension to the long-serving DOCSIS® specification. By expanding the spectrum capacity of coaxial cable, starting with the 1.8GHz milestone mapped out by the recently published DOCSIS® 4.0 specification, and then moving to 3GHz or higher, cable operators have identified a path for accommodating bandwidth upgrades for at least the next decade or two.



The human condition dictates that the potential to always be moving forward with technology is omnipresent and it is important to realise that the materials and technologies that society views as progressive and "new" today might already be "old things" in some other circles.

Thankyou for allowing me to present to you

today.

The COVID-19 crisis is a challenging time for everyone. We hope you and your family are keeping safe and staying well throughout this difficult time.

REFERENCES

1. "The Path to 10G:2020 Update,INFORMED- BLOG by CableLabs, Jan 3, 2020 – Mariam Sorond
2. "The 2050 Project:Part 1," - WWW.ATX.COM
3. "Communications Day Article 27 August 2020 :The Father of DSL says FTTN net can be re-purposed as giant distributed 5G antennae net,"– Professor John Cioffi
4. "Communications Day Article 25 August 2020 :The argument for Upgrading NBN's HFC plant," – Dermot Cox, Consulter
5. "Using DOCSIS" to Meet the Larger BW Demand of the 2020 Decade and Beyond," - Tom Cloonan, Ayham Al-Banna, Frank O'Keefe. CommScope
6. "Post by Trevor Long on March 15, 2018."
7. "Upgrades on the cards as NBN Co secures extra $4billion from banks."-Fergus Hunter, The Sydney Morning Herald May 12, 2020
8. "Comparing the DOCSIS" 3.1 and HFC Evolution to the FTTH Revolution," 2015 : Michael Emmendorfer - ARRIS
9. "Review of nbn's network selection methodology and the efficiency and prudency of the design of its FTTN, FTTB and HFC networks," April 2016 – Amrish Kacker,Frank Chevalier, Rod Parker, Rupert Wood. Analysys Mason Limited-Public Version.
10. HFC Network Capacity Evolution - https://mktg-webtestext.arris.com/solutions/access-network-evolution-framework/
11. Through to 2023 and Beyond - https://i.nextmedia.com.au/News/NBN_tech_options.png. IT News

This is a list of most excellent references.

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