Managing Interference in a Vectored VDSL2 environment

Communications Alliance WC58

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Communications Alliance Working Committee 58

CA Working Committee 58
VDSL2 and Vectoring

- Communications Alliance Working Committee 58 (WC58) is a group of VDSL2 and Fibre-To-The-Node (FTTN) technical experts representing members of the communications industry.

- WC58 is responsible for the industry codes and standards that ensure harmonious deployment of xDSL technology on copper access cables.
  - Crosstalk and interference
  - Transmit power levels
  - Rules to facilitate coexistence of services sharing the same cables

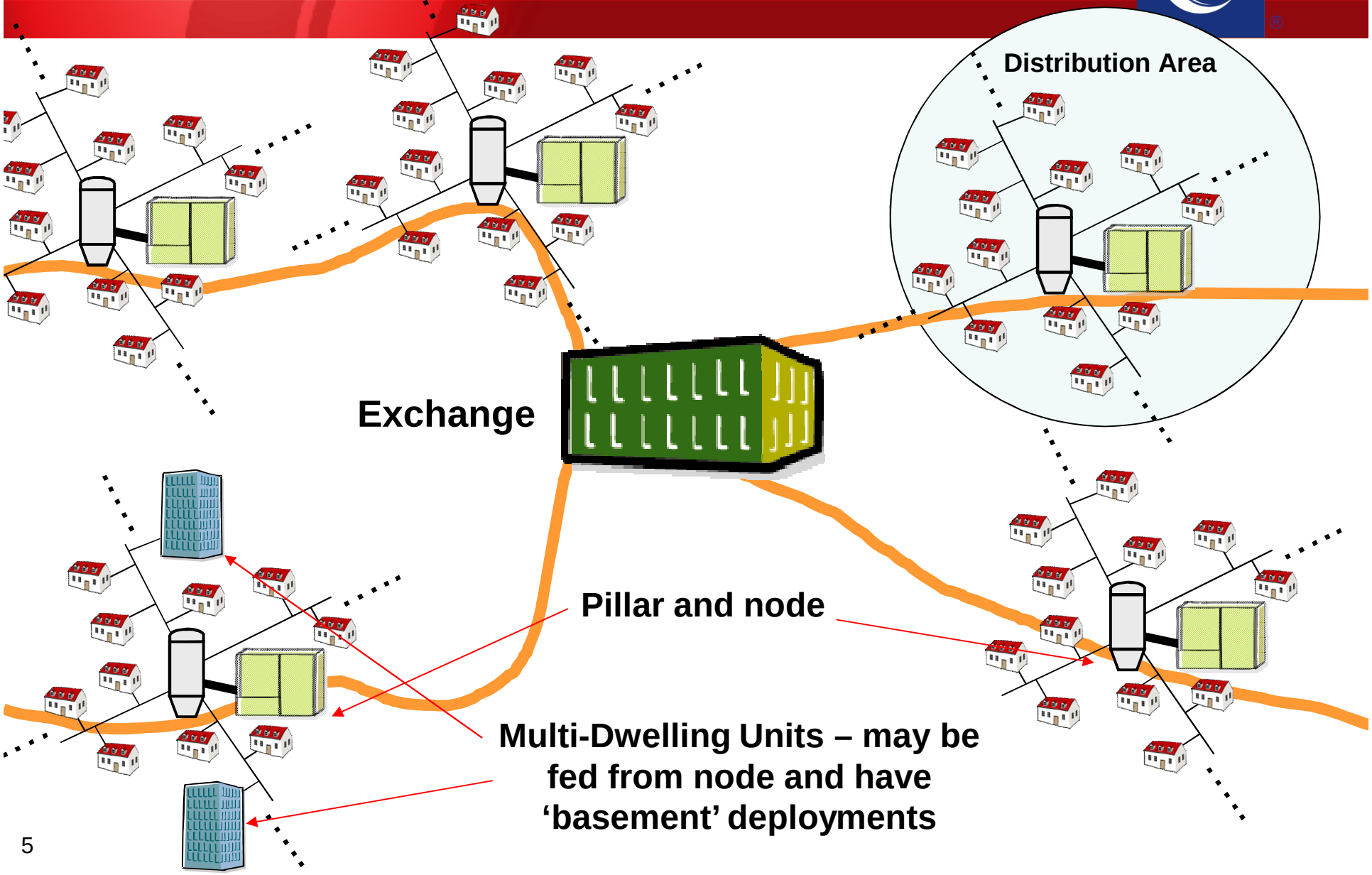
- WC58 has been considering the introduction of VDSL2 and FTTN technology in light of the Government's policies
  - Understanding the role of VDSL2 Vectoring
  - Considering how to manage VDSL2 spectrum in cables
  - Considering the transition from today's network to FTTN and FTTB
  - Exploring the technical implications of having more than one VDSL2 DSLAM sharing the cables

Balancing the key policy objectives with the technical implications

- The committee has been considering the engineering and technical implications of the following key policy objectives
  - **"… providing download data rates (and proportionate upload rates) of at least 25 megabits per second to all premises…"**
  - **"… and at least 50 megabits per second to 90 per cent of the fixed line premises as soon as possible."**
  - **"… at least cost to taxpayers."**
  - Source http://www.communications.gov.au/__data/assets/pdf_file/0014/221162/SOE_Shareholder_Minister_letter.pdf

Technical refresher

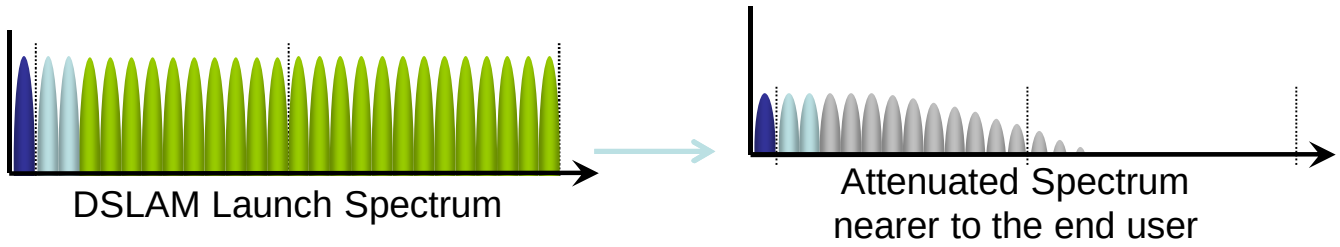
The Fibre To The Node architecture



Attenuation of signals on copper

- DSL services are delivered using the frequency spectrum available on traditional 'twisted pair' telephone lines

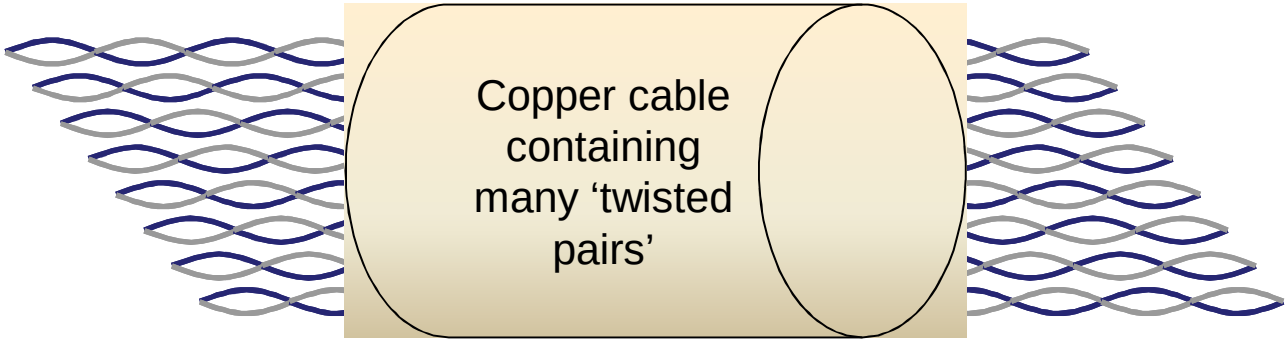
- DSL signals are attenuated as they travel along the twisted pairs, as light dims as it travels through fog



- Lines with higher attenuation achieve lower bit rates
  - To engineer the policy's bit-rate objectives, cable distances must be strictly managed in an engineering sense

Spectrum sharing on copper

- xDSL services in the same cables leak signals between each other and this causes interference and reduces rates
  - the higher the xDSL bit rate, the broader the signal leakage and interference

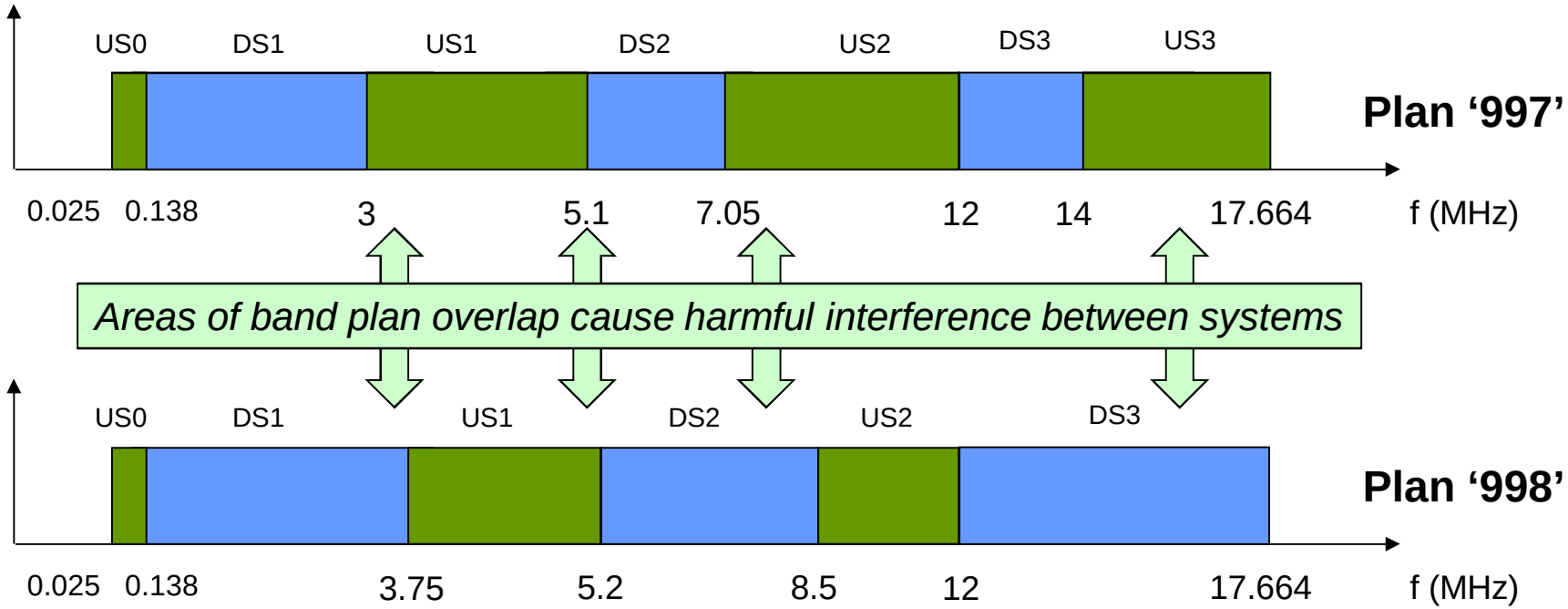


  - This is called 'crosstalk', and it exists because we are transmitting signals!
  - Crosstalk occurs between ALL xDSL lines sharing the same cable
  - Crosstalk has been traditionally managed by defining rules that govern spectral usage, transmit power levels and other kinds of deployment rules

- Vectoring is a new technology that can cancel most crosstalk
  - Vectoring gains are much greater than possible through traditional spectrum management approaches alone
  - **Vectoring is only effective when there is a single DSLAM** feeding each cable

The need for harmonised spectrum usage

- If VDSL2 systems from different DSLAMs share the same access or building cabling, then they need to have compatible band plans
  - any overlap of up and downstream signals in the same spectral region severely reduces rates in that part of the spectrum
- It is not straightforward for CA to mandate a VDSL2 band plan under current regulation

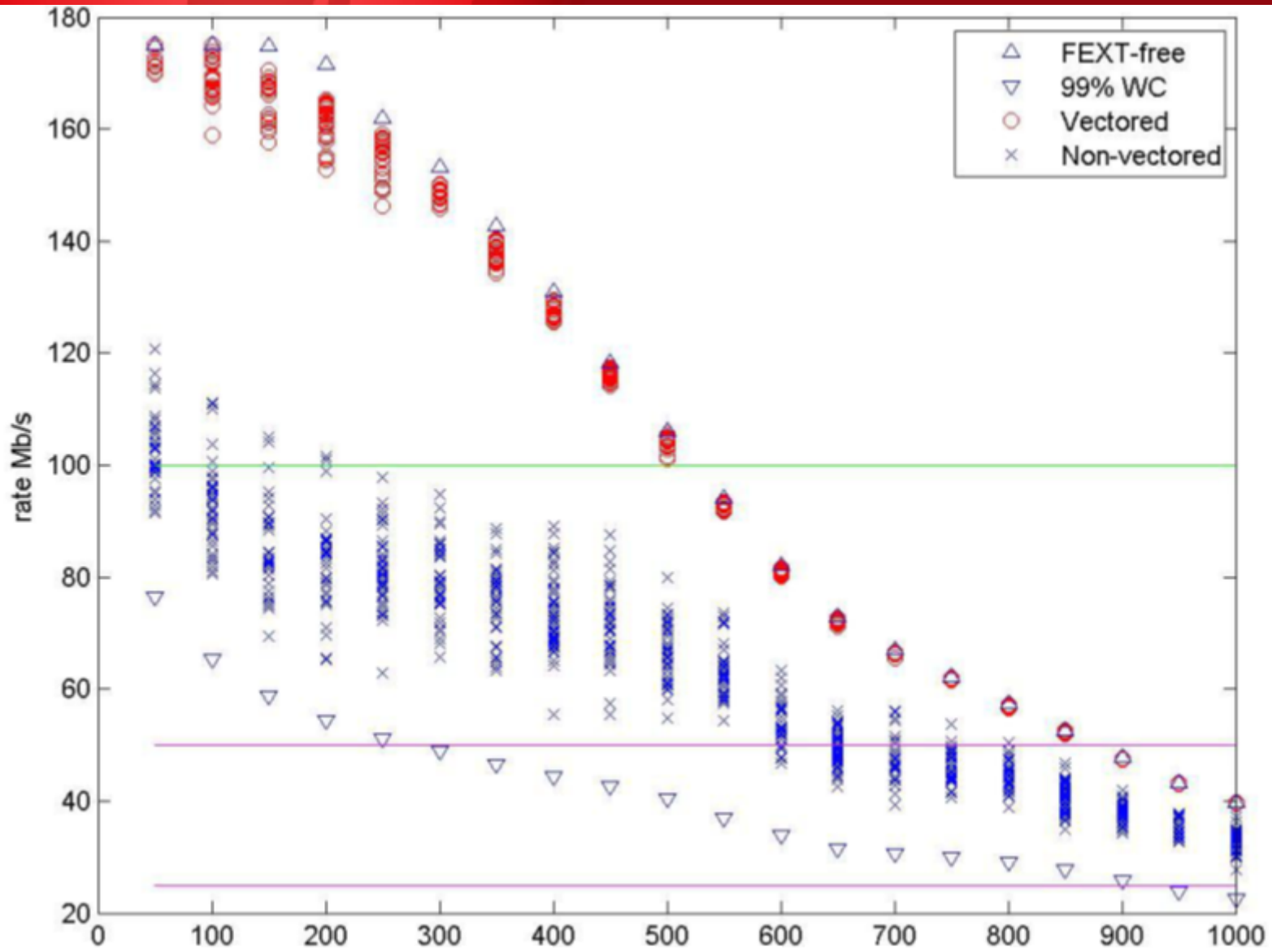


VDSL2 vectoring

VDSL2 Vectoring

- The latest VDSL2 standards support an interference cancellation technology called ‘vectoring’
  - Vectoring only works with VDSL2,
  - Vectoring is only fully effective if the rollout is planned for vectoring from day 1
  - Vectoring still partially works for VDSL2 users when ADSL / ADSL2+ services share the cable, but with reduced gains. For most vectored VDSL2 end users, the reduction when coexisting is < ~20%
  - Vectoring is only effective when all signals share the same band-plan
- Vectoring allows VDSL2 users to simultaneously achieve near theoretical maximum performance (for their cable length)
  - If effectively deployed, vectoring allows the same footprint to be served by significantly fewer nodes, still meeting the bit-rate policy objectives
- The catches
  - Vectoring is only effective when there is a single VDSL2 DSLAM feeding the cable
  - Adding vectoring hardware typically adds around 50% per line to the cost of the DSLAM
  - Vectoring requires greater operating power than regular VDSL2

Theoretical VDSL2 Vectoring gains



Source: Broadband Forum MR257 figure 6

Depicted rates are inclusive of Layer 2 overheads. Layer 2 rates would be approximately 10% lower.

Vectoring implementations limit the sum of the download plus upload to 160 Mbps. 110 Mbps download and 50 Mbps upload is possible, whereas 120 Mbps download and 50 Mbps upload is not.

End user ‘speed tests’ will normally report results between 10% and 15% below the Layer 2 rate.

Vectored VDSL2 speed

- Vectored VDSL2 has its speed reduced by other systems sharing the same access or building cabling (most severe first):
  1. **Another VDSL2 DSLAM located closer to the end user (e.g. in a building basement)**
  2. **Another collocated VDSL2 DSLAM**
  3. **ADSL or other legacy broadband services from a DSLAM located closer to the end user**
  4. **ADSL or other legacy broadband services from the same node or another collocated DSLAM**
  5. **ADSL or other legacy broadband services from a more distant location (e.g. From a Top Hat or from the exchange)**

- Some sharing such as 4 and 5 above may be acceptable and consistent with the long-term policy during a 'transition period'
  - However VDSL2 can only achieve its optimum performance in the long term when all interfering signals are removed
  - To minimise the cost of the roll out, engineer the network so that it will achieve the bit-rate objectives in the longer term when interfering signals are removed

Mid-Point Injection

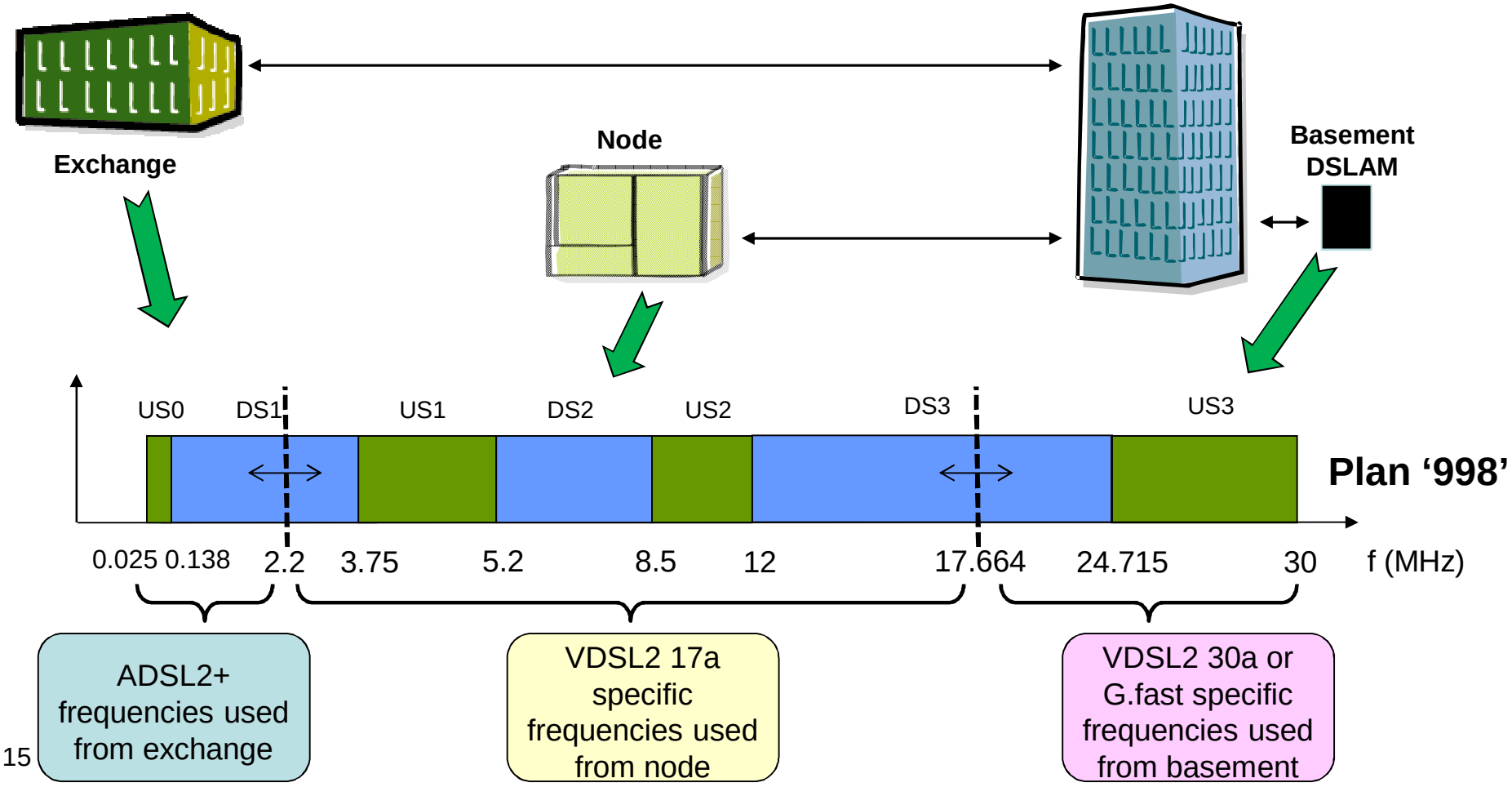
(mid span feed)

Mid point injection (aka Mid Span Feed)

- When two or more DSLAMs are installed in different places but their services share the same cables
  - Unequal crosstalk levels can have substantial performance impacts
  - If a first DSLAM is overbuilt by a second at a different location, the services from both can be significantly impacted (reduced rates and increased dropouts), or they can cease to work altogether
    - Often downstream will suffer substantially on one system, and upstream on the other
  - Technically, there are five kinds of management approaches; each kind of approach would lead to a different rollout cost and accrues different kinds of benefits
- Approach 1: 'Every DSLAM for itself' – no explicit controls
  - Exchange based DSL services likely to be harmed by node and basement services
  - Node based DSL services likely to be harmed by basement services
  - Some of the harmed DSL services may cease to function altogether
  - Under this approach, either the policy's bit rate or cost objectives would be unachievable, but this option maximises infrastructure competition opportunities (assuming the technical harm to services is acceptable to policy makers)

Mid point injection (continued)

- Approach 2: Spectral Separation – assign non-overlapping spectrum to each DSLAM



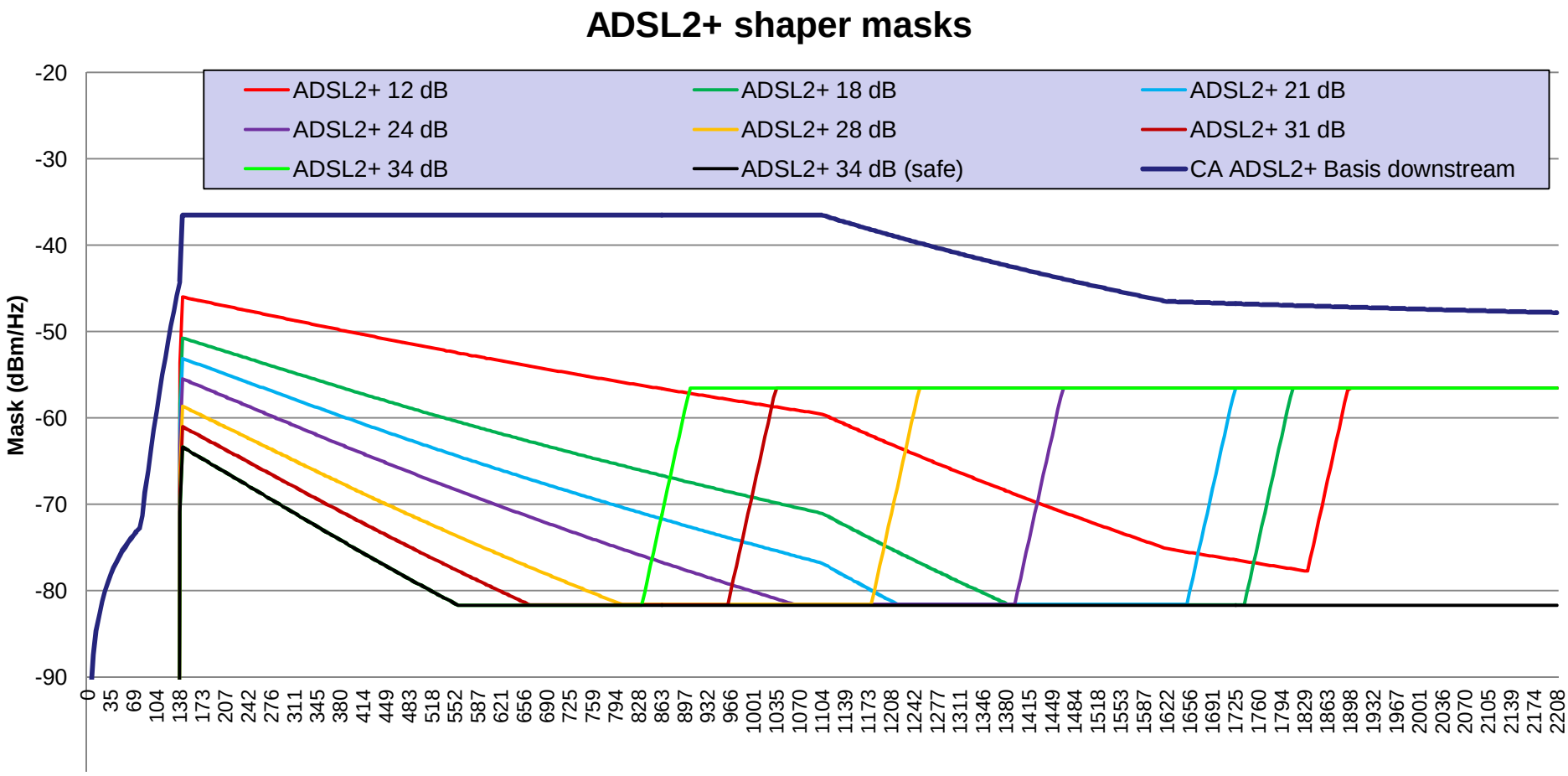
Mid point injection (continued)

- Approach 2: Spectral Separation – assign non-overlapping spectrum to each DSLAM
  - Exchange based DSL services are unharmed
  - Nodes only permitted to use the spectrum that is unusable from the exchange
  - Basement DSL services only permitted to use spectrum that is unusable from the exchange or node
  - Vectoring remains effective, but end user bit rates can be significantly constrained because of the scarcity of spectrum
  - **VDSL2 equipment is not normally deployed this way**.
  - Under this approach, testing would be required, and may ultimately show the approach to be not technically achievable for arbitrary combinations of DSLAMs and modems

Mid point injection (continued)

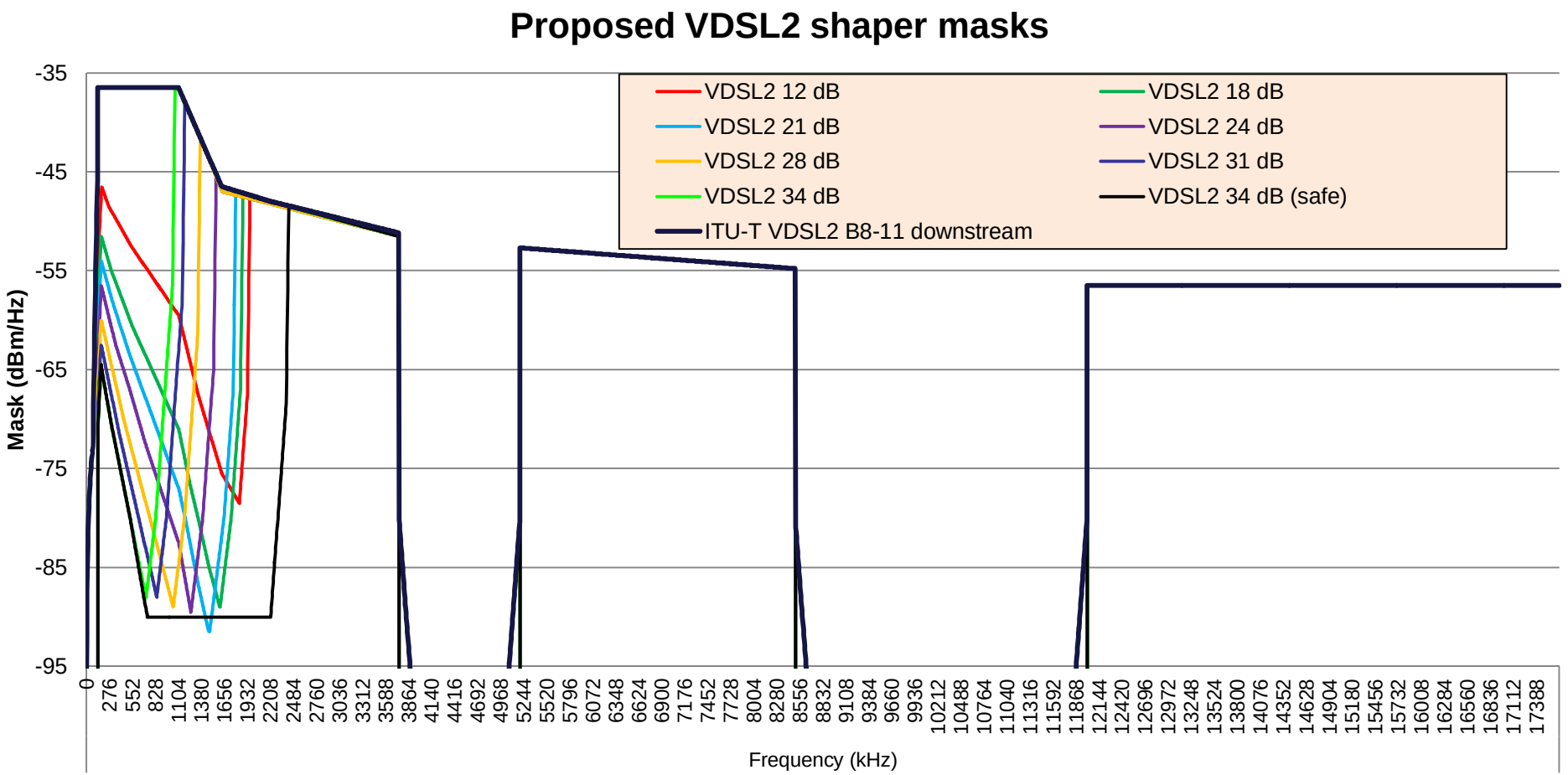
- Approach 3: Spectral Shaping
  - Exchange DSLAMs limited to ADSL2+, node and basement systems may use VDSL2
  - Exchange based ADSL2+ harmed no more than by other collocated exchange DSLAMs
  - Node VDSL2 services minimally constrained if no exchange or basement VDSL2 sharing the cables
    - VDSL2 vectoring ineffective if another VDSL2 DSALM does share the cables
  - Basement VDSL2 minimally constrained if no node or another basement VDSL2 system sharing the cables
    - VDSL2 vectoring ineffective if another VDSL2 DSALM does share the cables
  - Under this approach, vectoring gains may be severely constrained in the parts of the spectrum that are shared, or the benefits of vectoring may be foregone altogether
- Spectral shaping requires technically complex development of new rules, and updates to the C559 industry code
  - VDSL2 is not yet technically approved for deployment in Australia under the current code
  - Development and testing of the spectral shaping parameters is expected to take considerable time (6-12 months)

ADSL2+ spectral shaping in today's network



These spectrum shapers were approve for use by the committee to protect exchange based ADSL2+ and special services from node based ADSL2+

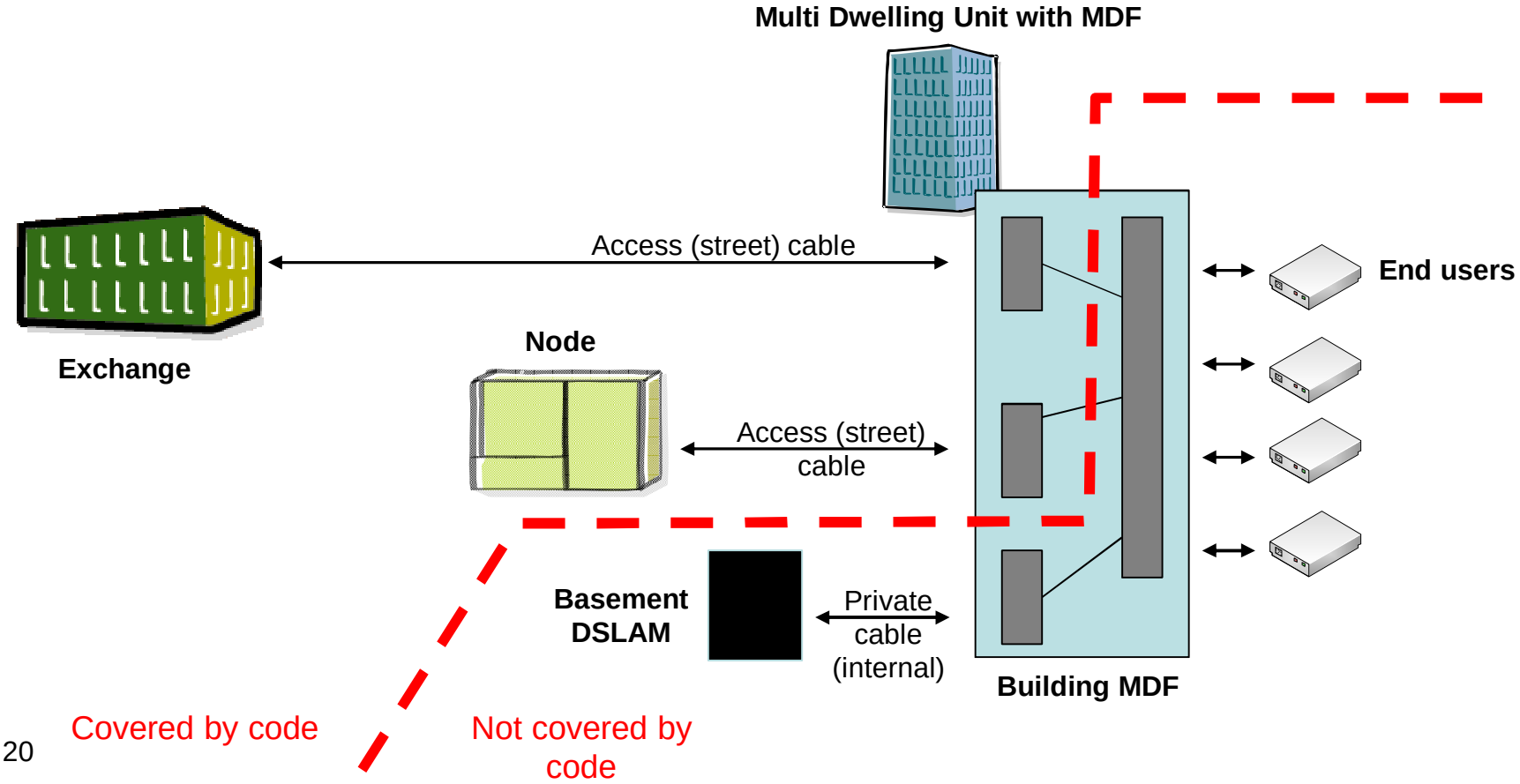
Proposed VDSL2 spectral shapers for the transition



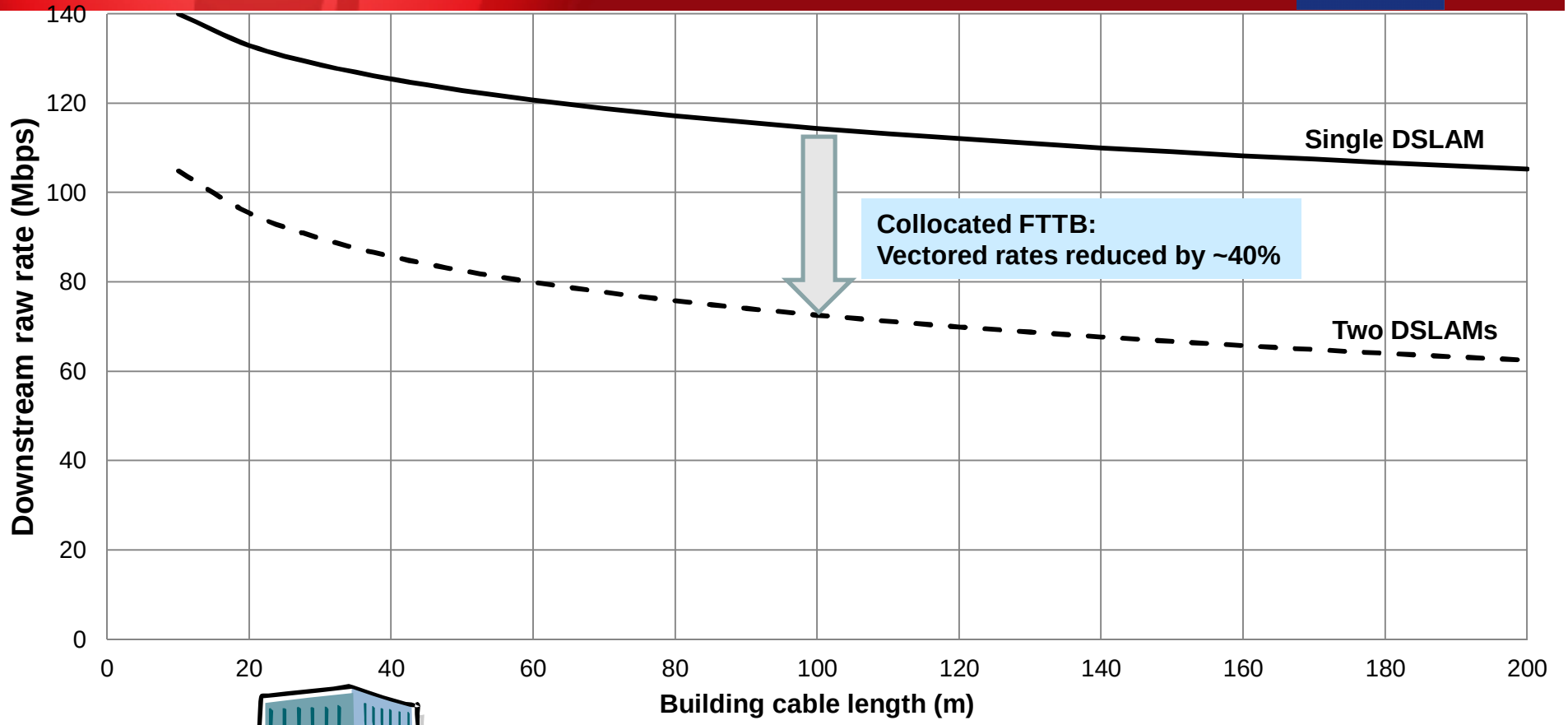
These spectrum shapers were approved for use by the committee to protect exchange or cabinet based ADSL2+ and special services from node or basement based VDSL2 , but are not intended to protect VDSL2 against VDSL2

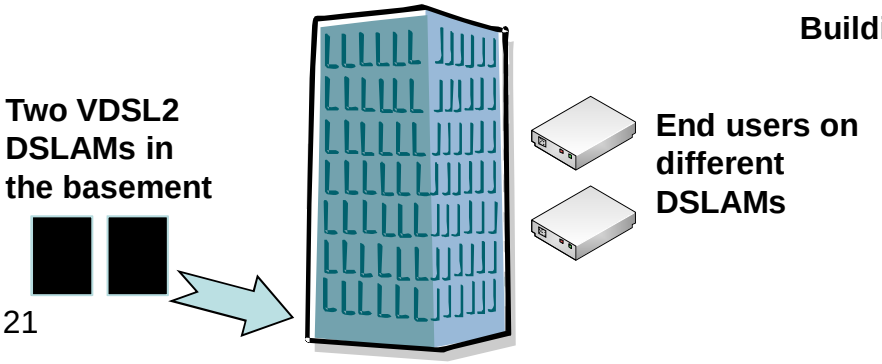
VDSL2 interference management in building cables

- Basement DSLAMs are not covered by the current spectrum management code
  - Private cables are not currently regulated



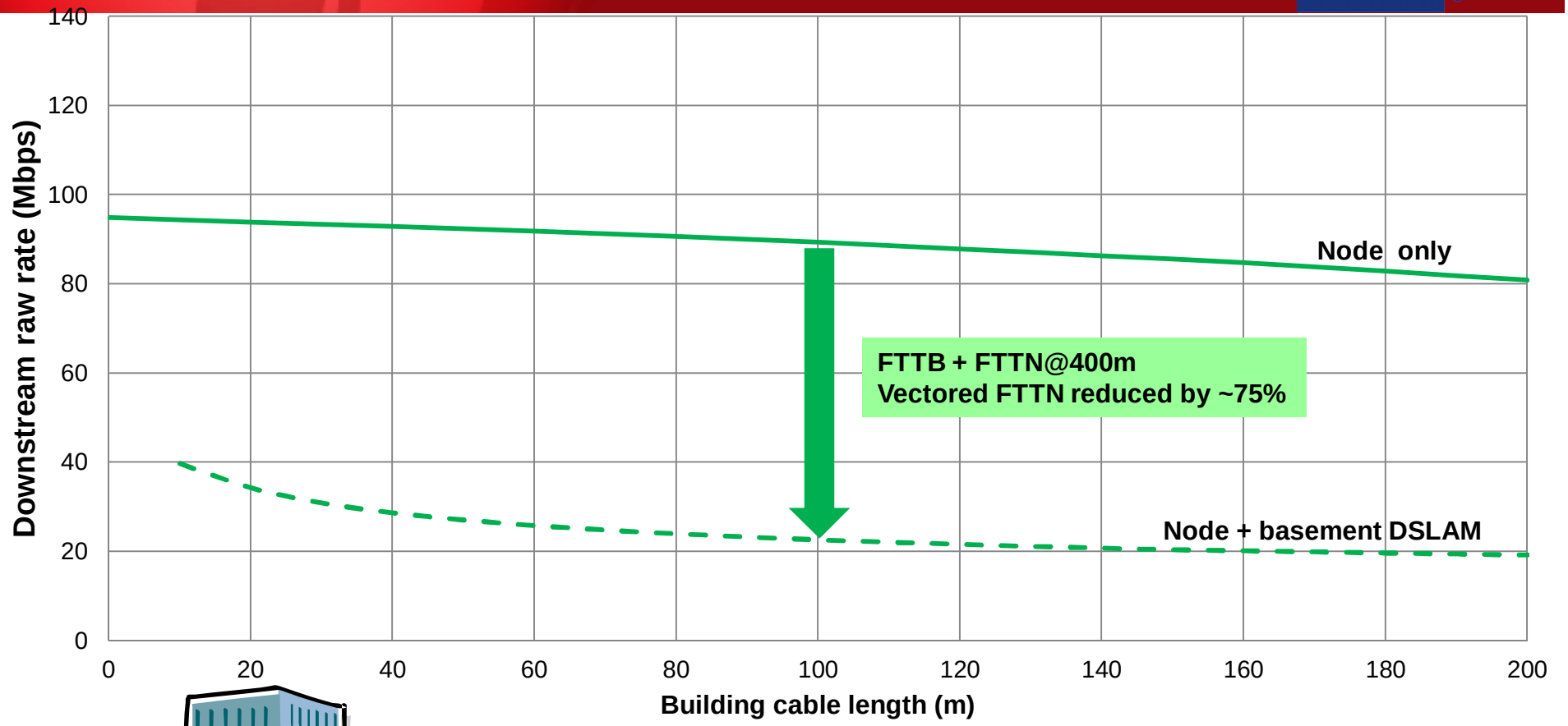
Vectored VDSL2 rate impact due to other VDSL2 in the same cable

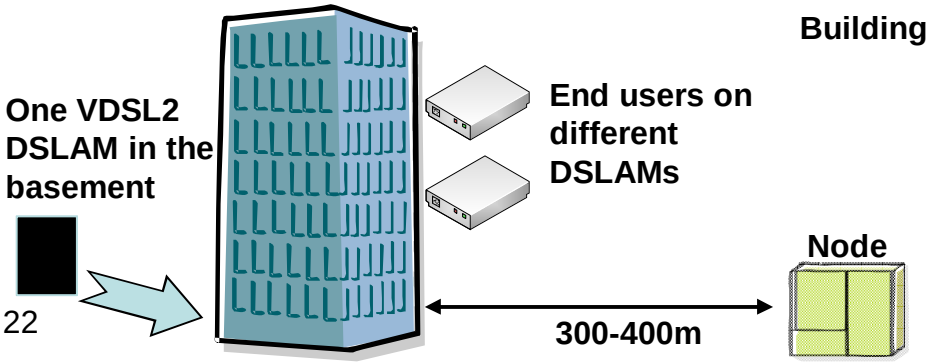




Note: Only for illustration of differences between cases. Rates on charts are based on calculations with typical network cables, noise conditions and implementation assumptions, but not aligned with parameters in any code or standard. Rates don't represent Layer 2.

Vectored VDSL2 rate impact due to other VDSL2 in the same cable





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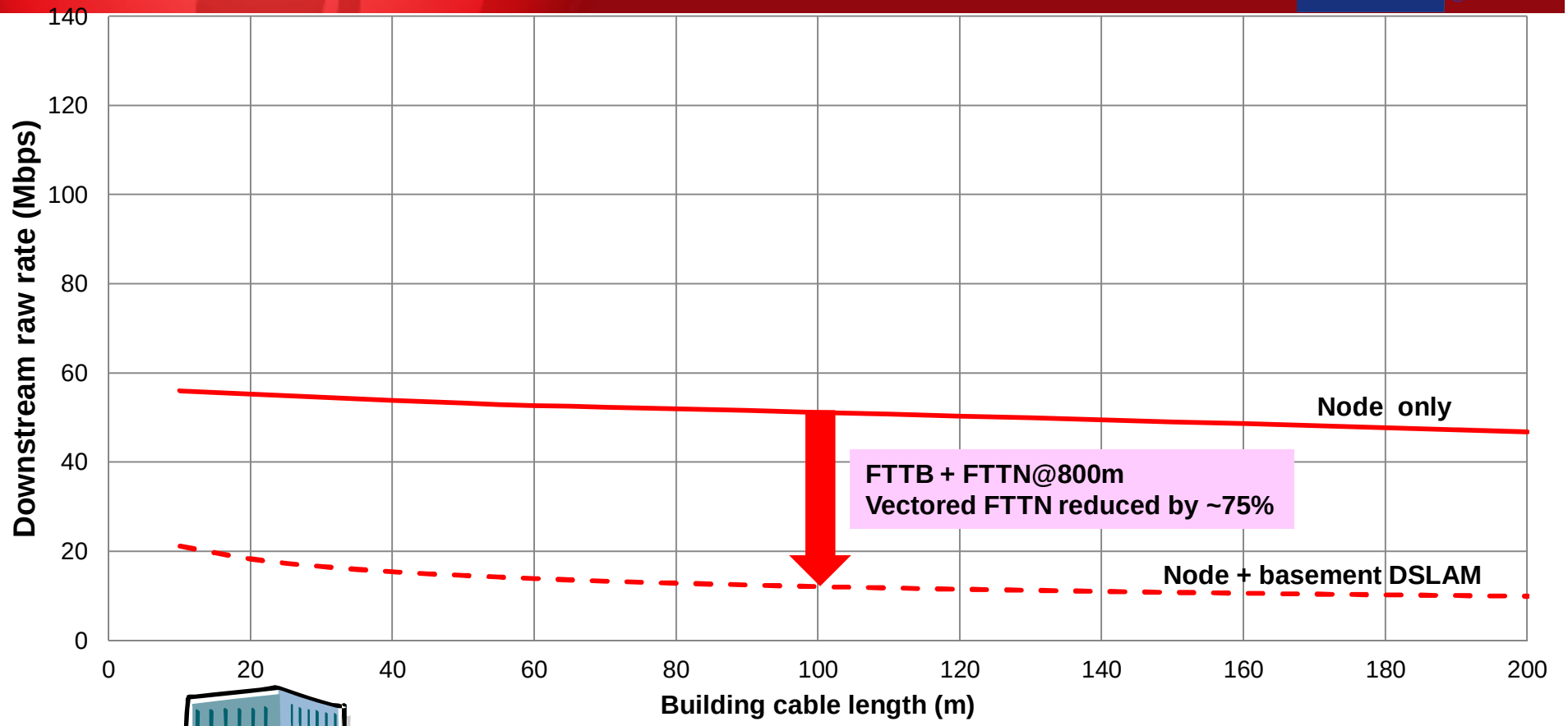

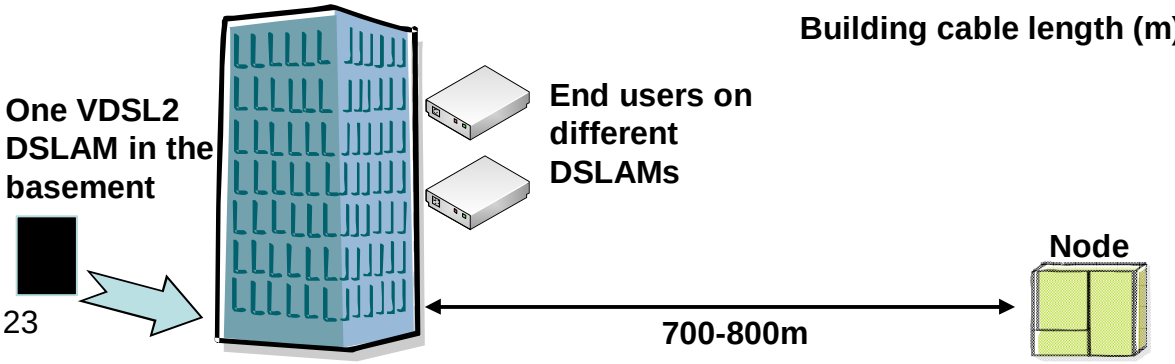

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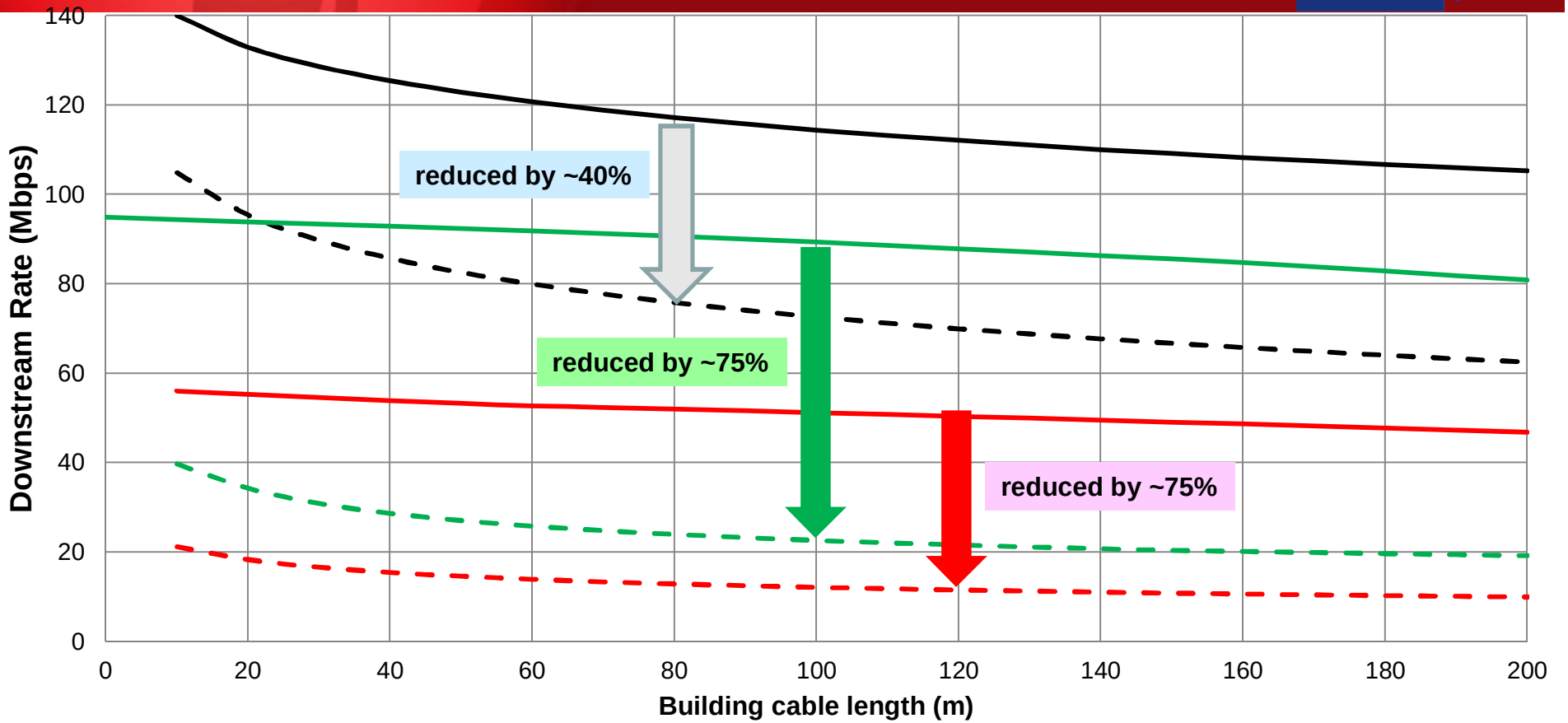

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VDSL2 interference management in building cables

- Interference management in building cables has so far not been regulated
- Two collocated basement systems would interfere with each other and render vectoring ineffective
  - Bit rate policy objectives would still likely be met in most buildings
  - Spectral shaping to protect legacy exchange and cabinet services would still be necessary during a transition
- Interference between basement and node or exchange VDSL2 systems would be much more severe
  - The interference could be so severe that cabinet services sharing the same in-building cables may operate at well below the 25/5 Mbps policy target rates
  - The actual outcome will depend on the cable length between the cabinet and building
  - If a first DSLAM is overbuilt by a second at a different location, the services from both can be significantly impacted (reduced rates and increased dropouts), or they can cease to work altogether

Mid point injection (continued)

- Approach 4: Segregated cables
  - Establish a rule that ensures that only services from a single VDSL2 DSLAM can share any cable segment
  - This means that every VDSL2 DSLAM requires a unique cable path from the DSLAM to the end user modem, which may not be shared with any other VDSL2 DSLAM
    - Generally, this will require new copper cables to be deployed between the DSLAM and the end user premises
  - Currently customer cabling, for example in Multi-Dwelling Units, is unregulated
  - Although C559 recommends separate building cabling for node and building systems, that is generally not an economic option for the second-in provider, and cannot be mandated in the current environment.
- Approach 5: Single VDSL2 operator per designated area
  - The technical outcome of this approach is similar to approach 4, avoiding the need to explicitly regulate customer cabling or install new cables, and still maximising the benefits of VDSL2 vectoring.
- Of the five approaches, 4 and 5 are technically the most straightforward way of maximising VDSL2 vectoring benefits in the fastest way with the lowest technical uncertainty

Matrix of scenarios requiring technical consideration

Technology impacted => ---------- Technology interfering	Exchange POTS victim	Exchange ADSL and special services victim	Exchange VDSL2 victim	TopHat ADSL victim	TopHat VDSL2 victim	Node VDSL2 victim	Micronode VDSL2 victim (see Note 9)	Building VDSL2 victim
Exchange POTS interferer			**14**			**15**	**16**	DSLAM splitter performance issues **17** (greatest impact to the longest VDSL2 and POTS lines)
Exchange ADSL and special services interferer			Non vectored performance in ADSL2+ band **1** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***		Non vectored performance in ADSL2+ band (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***	Non vectored performance in ADSL2+ band **2** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***	Non vectored performance in ADSL2+ band **3** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***	Non vectored performance in ADSL2+ band **4** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***
Exchange VDSL2 interferer	Note 7 **14**	**1**	Non vectored performance in all VDSL2 bands **5** (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	**1**	Mid Span Feed - VDSL2 US harmed + non-vectored (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed + non-vectored **6** (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed + non-vectored **7** (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed + non-vectored **8** (substantial impact to all VDSL2 lines) ** ***Building/Network Cable Sharing Rules Required***
TopHat ADSL interferer			Non vectored performance in ADSL2+ band **1** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***	Not Applicable (there is only ever one Top Hat at a location).	Not Applicable (there is only ever one Top Hat at a location).	Non vectored performance in ADSL2+ band **2** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***	Non vectored performance in ADSL2+ band **3** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***	Non vectored performance in ADSL2+ band **4** (moderate impact during transition) * ***All Legacy broadband services transition to FTTN VDSL2***
TopHat VDSL2 interferer			Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** ***Single Network Provider***	Not Applicable (there is only ever one Top Hat at a location).	Not Applicable (there is only ever one Top Hat at a location).	Mid Span Feed - VDSL2 US harmed + non-vectored (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed + non-vectored (less severe) (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed + non-vectored (substantial impact to all VDSL2 lines) ** ***Building/Network Cable Sharing Rules Required***
Node VDSL2 interferer	Note 7 **15**	**2**	Mid Span Feed - VDSL2 DS harmed + non-vectored **6** (extreme impact to all VDSL2 lines) *** ***Single Network Provider***	**2**	Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** ***Single Network Provider***	Non vectored performance in all VDSL2 bands **11** (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed(less severe) **9 or 11** (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed **10** (substantial impact to all VDSL2 lines) ** ***Building/Network Cable Sharing Rules Required***
Micronode VDSL2 interferer (see note 9)	Note 7 **16**	**3**	Mid Span Feed - VDSL2 DS harmed + non-vectored **7** (extreme impact to all VDSL2 lines) *** ***Single Network Provider***	**3**	Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** ***Single Network Provider***	Mid Span Feed - VDSL2 DS harmed + non-vectored **9 or 11** (extreme impact to all VDSL2 lines) *** ***Single Network Provider***	Non vectored performance in all VDSL2 bands **9 or 11** (substantial impact to all VDSL2 lines) ** ***Single Network Provider***	Mid Span Feed - VDSL2 US harmed(less severe) **10 or 12** (substantial impact to all VDSL2 lines) ** ***Building/Network Cable Sharing Rules Required***
Building VDSL2 interferer	DSLAM splitter performance issues and LSS compatibility issues **17** (greatest impact to the longest telephone lines) ***Enforce POTS requirements***	Mid Span Feed - ADSL2+ band DS harmed **4** (extreme impact to all ADSL lines) *** ***Mandatory spectral shaping of building systems during***	Mid Span Feed - VDSL2 DS harmed + non-vectored **8** (extreme impact to all VDSL2 lines) *** ***Building /NetworkCable Sharing Rules Required***	Mid Span Feed - ADSL2+ band DS harmed **4** (extreme impact to all ADSL lines) *** ***Mandatory spectral shaping of building systems during***	Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** ***Building/Network Cable Sharing Rules Required***	Mid Span Feed - VDSL2 DS harmed + non-vectored **10** (extreme impact to all VDSL2 lines) *** ***Building/Network Cable Sharing Rules Required***	Mid Span Feed - VDSL2 DS harmed + non-vectored **10 or 12** (substantial impact to all VDSL2 lines) *** ***Building/Network Cable Sharing Rules Required***	Non vectored performance in all VDSL2 bands **13** (substantial impact to all VDSL2 lines) ** ***Multiple building system regulation***

Vectored VDSL2 impact scenarios

- The committee's key findings, which underlie the matrix, can be summarised in the same short list of vectored VDSL2 impact scenarios presented earlier (most severe first):

  1. **Another VDSL2 DSLAM located closer to the end user (e.g. in a building basement)**
  2. **Another collocated VDSL2 DSLAM**
  3. **ADSL or other legacy broadband services from a DSLAM located closer to the end user**
  4. **ADSL or other legacy broadband services from the same node or another collocated DSLAM**
  5. **ADSL or other legacy broadband services from a more distant location (e.g. From a Top Hat or from the exchange)**

- The matrix also shows need for consideration of the technical requirements necessary to maintain the quality of POTS services

Summary of possible technical resolutions

- To proceed, the committee awaits clarification of which kind of rules are preferred for managing spectrum in building and network cables
  - Spectral shaping, or
  - Spectral separation, or
  - Segregated cables, or
  - Single provider of vectored VDSL2
  - The approach that is ultimately selected will establish the base line engineering and business case benchmarks for the national FTTN/FTTB roll out
  - A hybrid of two or more of these approaches may be possible and may help harmonise technical constraints with policy
- The committee has recommended extending regulatory powers to cover in-building systems
  - Establish a common band-plan for all cables, including in-building cables
  - Require providers of in-building systems to shape signals during a transition
  - Require providers of in-building systems to adhere to the same chosen spectrum management approach applying to network cables
  - Require providers of in-building systems to honour technical requirements pertaining to POTS when the in-building service is a Line Sharing Service

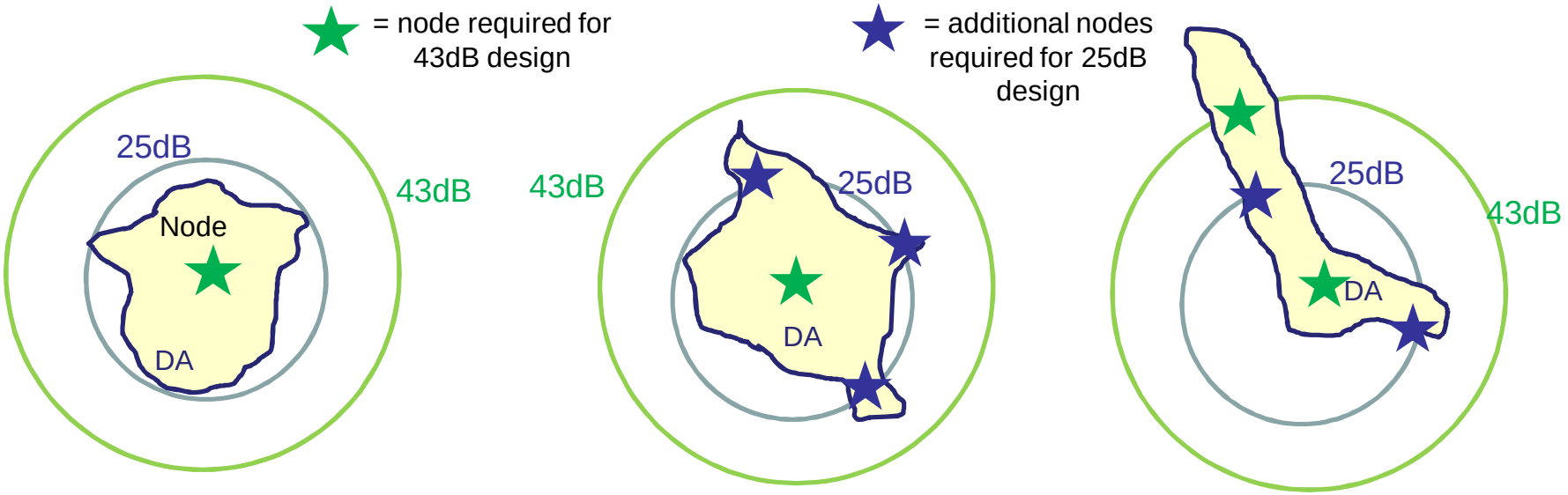
Engineering the Australian FTTN/B roll out to achieve the policy objectives

VDSL2 node placement

- Minimising the number of FTTN + FTTB nodes will minimise the cost of the national roll out
- The number of nodes will primarily depend on the maximum distance at which 25/5 Mbps can be confidently achieved
  - Largest reach will be achieved when VDSL2 vectoring is fully effective
  - Shorter reach when VDSL2 vectoring is not effective, or for an unvectored design
- Effectively vectored VDSL2 on typical Australian 0.4mm cable:
  - can reach ~1.1km for 25/5 Mbps (around 43 dB attenuation at 3.75 MHz)
  - can reach ~750m for 50/10 (estimated to cover ~90% of premises)
- Unvectored VDSL2 on typical Australian 0.4mm cable:
  - can reach ~650m for 25/5 Mbps (around 25 dB at 3.75 MHz)
  - insufficient data today to be sure 50/10 Mbps is achievable to 90% at 650m
- An additional node or micronode is required to satisfy the bit-rate policy wherever the attenuation exceeds these engineering limits

VDSL2 design approach necessary to meet the 25/5 policy objective

- Most DAs have multiple cable routes radiating from the pillar
  - an additional node or micronode is required for each cable route that exceeds the engineering limit.

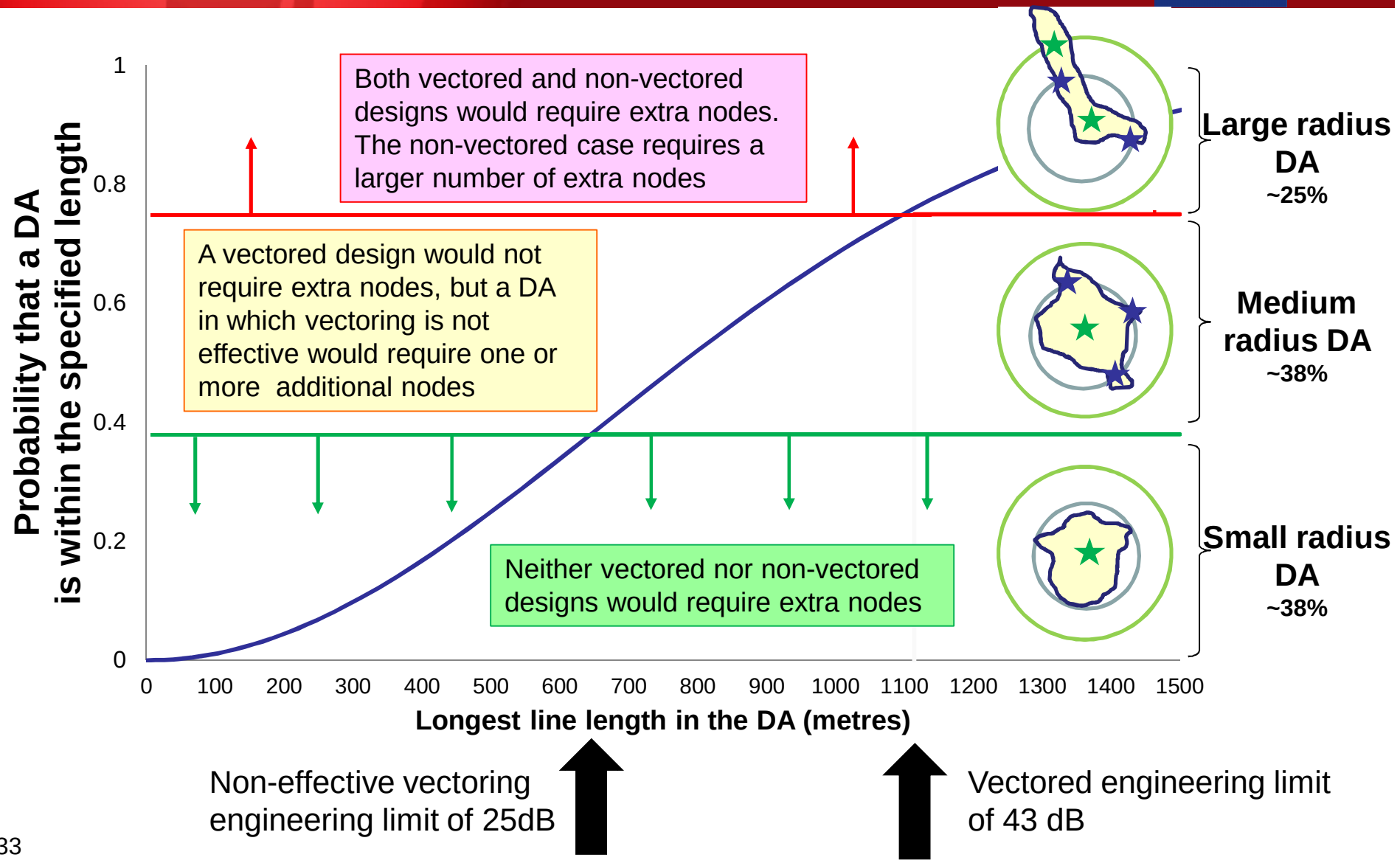


Small radius DA:
A single node (using either vectored or unvectored VDSL2 can satisfy both policy objectives

Medium radius DA:
A single effectively vectored node satisfies the policy objectives on its own. Additional nodes or micronodes necessary if vectoring not effective.

Large radius DA:
Additional nodes or micronodes are required even if vectoring effective. The number of additional nodes is greater if vectoring is ineffective.

Vectored vs non-vectored design



The practical engineering outcome

- If vectoring is ineffective in the long-term, achieving the 25/5 Mbps policy implies at least 50% more nodes, or possibly more
  - There is likelihood that a second-in DSLAM will degrade or disrupt services from a first-in DSLAM that was designed to meet the effective-vectoring limit
  - Therefore recommend to adopt and deploy using the unvectored design limits if effective-vectoring cannot be assured
  - A comprehensive study including every FTTN rollout area in Australia would be necessary to accurately define the number of additional nodes
- If additional nodes are necessary, the roll out must therefore be less cost effective than for fewer nodes

Where the committee stands today

Recall that WC58 has been considering vectored VDSL2 deployment scenarios in light of the policy

Matrix of scenarios requiring technical consideration

Technology impacted => / Technology interfering	Exchange POTS victim	Exchange ADSL and special services victim	Exchange VDSL2 victim	TopHat ADSL victim	TopHat VDSL2 victim	Node VDSL2 victim	Micronode VDSL2 victim (see Note 9)	Building VDSL2 victim
Exchange POTS interferer			14			15	16	DSLAM splitter performance issues 17 (greatest impact to the longest VDSL2 and POTS lines)
Exchange ADSL and special services interferer			Non-vectored performance in ADSL2+ band 1 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*		Non-vectored performance in ADSL2+ band (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*	Non-vectored performance in ADSL2+ band 2 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*	Non-vectored performance in ADSL2+ band 3 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*	Non-vectored performance in ADSL2+ band 4 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*
Exchange VDSL2 interferer	Note 7 14	1	Non-vectored performance in all VDSL2 bands 5 (substantial impact to all VDSL2 lines) ** *Single Network Provider*	1	Mid Span Feed - VDSL2 US harmed + non-vectored (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 US harmed + non-vectored 6 (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 US harmed + non-vectored 7 (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 US harmed + non-vectored 8 (substantial impact to all VDSL2 lines) ** *Building/Network Cable Sharing Rules Required*
TopHat ADSL interferer			Non-vectored performance in ADSL2+ band 1 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*	Not Applicable (there is only ever one Top Hat at a location).	Not Applicable (there is only ever one Top Hat at a location).	Non-vectored performance in ADSL2+ band 2 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*	Non-vectored performance in ADSL2+ band 3 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*	Non-vectored performance in ADSL2+ band 4 (moderate impact during transition) * *All Legacy broadband services transition to FTTN VDSL2*
TopHat VDSL2 interferer			Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** *Single Network Provider*	Not Applicable (there is only ever one Top Hat at a location).	Not Applicable (there is only ever one Top Hat at a location).	Mid Span Feed - VDSL2 US harmed + non-vectored (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 US harmed + non-vectored (less severe) (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 harmed + non-vectored (substantial impact to VDSL2 lines) ** *Building/Network Cable Sharing Rules Required*
Node VDSL2 interferer	Note 7 15	2	Mid Span Feed - VDSL2 DS harmed + non-vectored 6 (extreme impact to all VDSL2 lines) *** *Single Network Provider*	2	Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** *Single Network Provider*	Non-vectored performance in all VDSL2 bands 11 (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 US harmed (less severe) 9 or 11 (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 harmed 10 (substantial impact to VDSL2 lines) ** *Building/Network Cable Sharing Rules Required*
Micronode VDSL2 interferer (see note 9)	Note 7 16	3	Mid Span Feed - VDSL2 DS harmed + non-vectored 7 (extreme impact to all VDSL2 lines) *** *Single Network Provider*	3	Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** *Single Network Provider*	Mid Span Feed - VDSL2 DS harmed + non-vectored 9 or 11 (extreme impact to all VDSL2 lines) *** *Single Network Provider*	Non-vectored performance in all VDSL2 bands 9 or 11 (substantial impact to all VDSL2 lines) ** *Single Network Provider*	Mid Span Feed - VDSL2 harmed (less severe) 10 or 12 (substantial impact to all VDSL2 lines) ** *Building/Network Cable Sharing Rules Required*
Building VDSL2 interferer	DSLAM splitter performance issues and LSS compatibility issues 17 (greatest impact to the longest telephone lines) *Enforce POTS requirements*	Mid Span Feed - ADSL2+ band DS harmed 4 (extreme impact to all ADSL lines) *** *Mandatory spectral shaping of building systems during*	Mid Span Feed - VDSL2 DS harmed + non-vectored 8 (extreme impact to all VDSL2 lines) *** *Building /Network Cable Sharing Rules Required*	Mid Span Feed - ADSL2+ band DS harmed 4 (extreme impact to all ADSL lines) *** *Mandatory spectral shaping of building systems during*	Mid Span Feed - VDSL2 DS harmed + non-vectored (extreme impact to all VDSL2 lines) *** *Building/Network Cable Sharing Rules Required*	Mid Span Feed - VDSL2 DS harmed + non-vectored 10 (extreme impact to all VDSL2 lines) *** *Building/Network Cable Sharing Rules Required*	Mid Span Feed - VDSL2 DS harmed + non-vectored 10 or 12 (substantial impact to all VDSL2 lines) *** *Building/Network Cable Sharing Rules Required*	Non-vectored performance in all VDSL2 bands 13 (substantial impact VDSL2 lines) ** *Multiple building syste regulation*

Vectored VDSL2 impact scenarios

- The committee's key findings, which underlie the matrix, can be summarised in the same short list of vectored VDSL2 impact scenarios presented earlier (most severe first):

1. **Another VDSL2 DSLAM located closer to the end user (e.g. in a building basement)**
2. **Another collocated VDSL2 DSLAM**
3. **ADSL or other legacy broadband services from a DSLAM located closer to the end user**
4. **ADSL or other legacy broadband services from the same node or another collocated DSLAM**
5. **ADSL or other legacy broadband services from a more distant location (e.g. From a Top Hat or from the exchange)**

- The matrix also shows need for consideration of the technical requirements necessary to maintain the quality of POTS services

Where the committee stands today

- The committee of VDSL2 and vectoring technical experts has drafted changes to the C559 industry code.
  - the committee has considered each scenario, and
  - **the draft changes enable the key policy objectives to be achieved**
    - i.e. enable 25/5 Mbps to be available to all, and 50/10 Mbps to be available to 90%, at least cost to taxpayers
- Assumptions
  - Segregated cables or single vectored VDSL2 provider per area for effective vectoring
  - Transition during which vectored VDSL2 will coexist with legacy technologies
  - Transition will allow FTTN/B roll out to be engineered for long term, fulfilling least cost policy
  - Spectral shaping applied during transition to avoid degrading legacy services
  - Following transition, VDSL2 spectral shaping will be removed. Vectored VDSL2 will then fulfil the 25/5 and 50/10 policies where legacy services have been fully retired
  - The committee's submissions to Vertigan and subsequent follow up have assumed that in-building cable will need to be subject to the code or a unifying policy that ties FTTN and FTTB deployment rules together
- The draft is ready to be issued for public comment, but awaiting confirmation the assumptions are acceptable
  - Alternately, the committee would be pleased to undertake the necessary research to update the code in accordance with the preferred policy clarifications