Broadband prospects on copper networks

New developments related to G.fast

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Different developments for different use cases

Developments:

- Currently in progress (short term):
  - VDSL/35b (*branded as : "Vplus", "super vectoring", "extended VDSL"*)
  - G.fast, first generation (*up to 106 MHz*)
    - Support of bigger vector groups (>16, *32?, 48?*)
    - Support of bonding
- 1. Reach-extended G.fast (>350m, large vector groups)
- 2. Copper backhauling (to prevent lots of fiber digging)
- 3. Next generation G.fast (up to 212 MHz)
- 4. Beyond G.fast (up to 7 Gb/s)

Use cases:

- FTTB (high rise buildings, multi tenant houses)
- Gradual migration in dense city areas (100>200>400Mb/s)
- Disruptive migration in dense city areas (500>1000Mb/s)
- FTTH, with copper extension
- …

1. Reach-extended G.fast (longer loops)

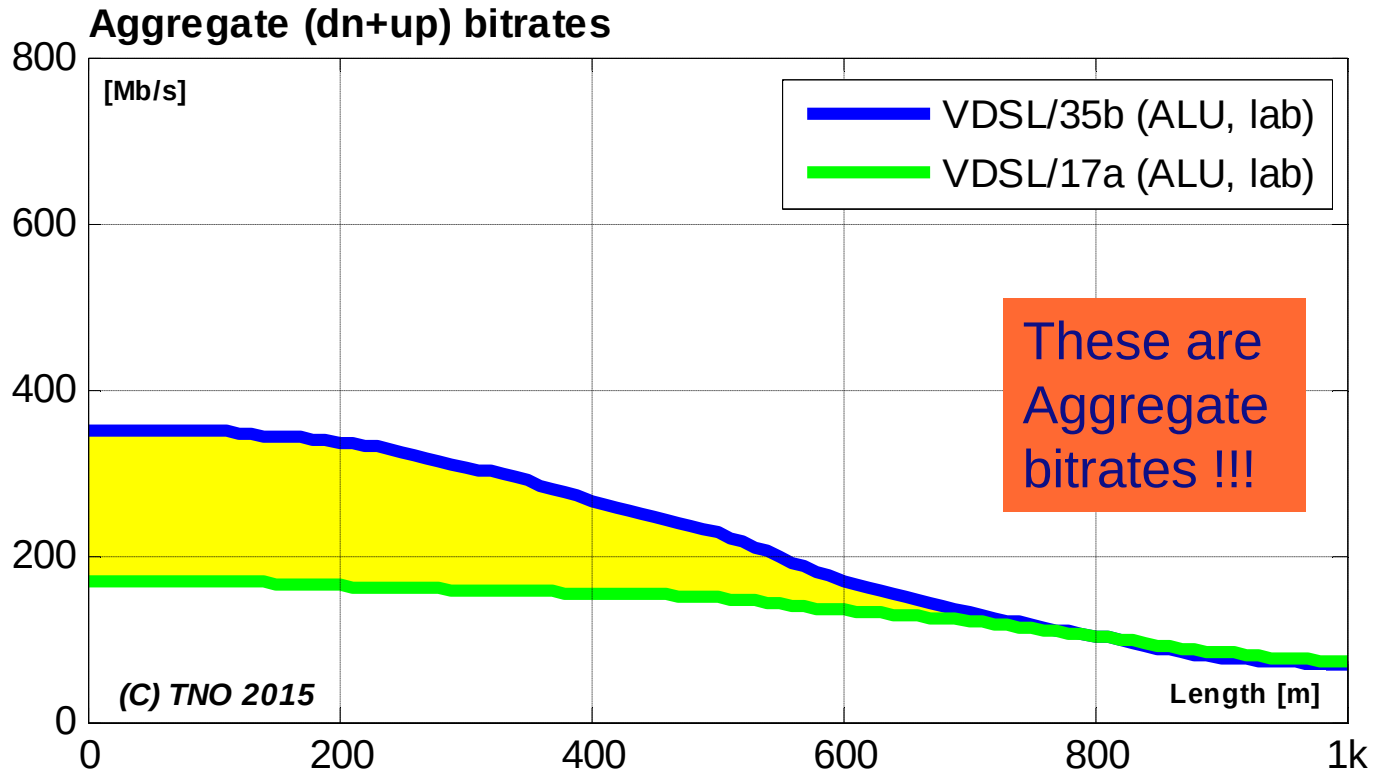
Typical use case: migrations in dense city areas

- Gradual (and disruptive) migrations
- Typically from cabinets that are not activated yet
- Should be usable up to 300-600m
- Should handle 100-200 broadband subscribers per cabinet

G.fast has significant potential for cabinet deployments

- G.fast was never designed for this (aim: 20-200m)
- Current G.fast versions show already nice performance
- Required G.fast improvements are doable

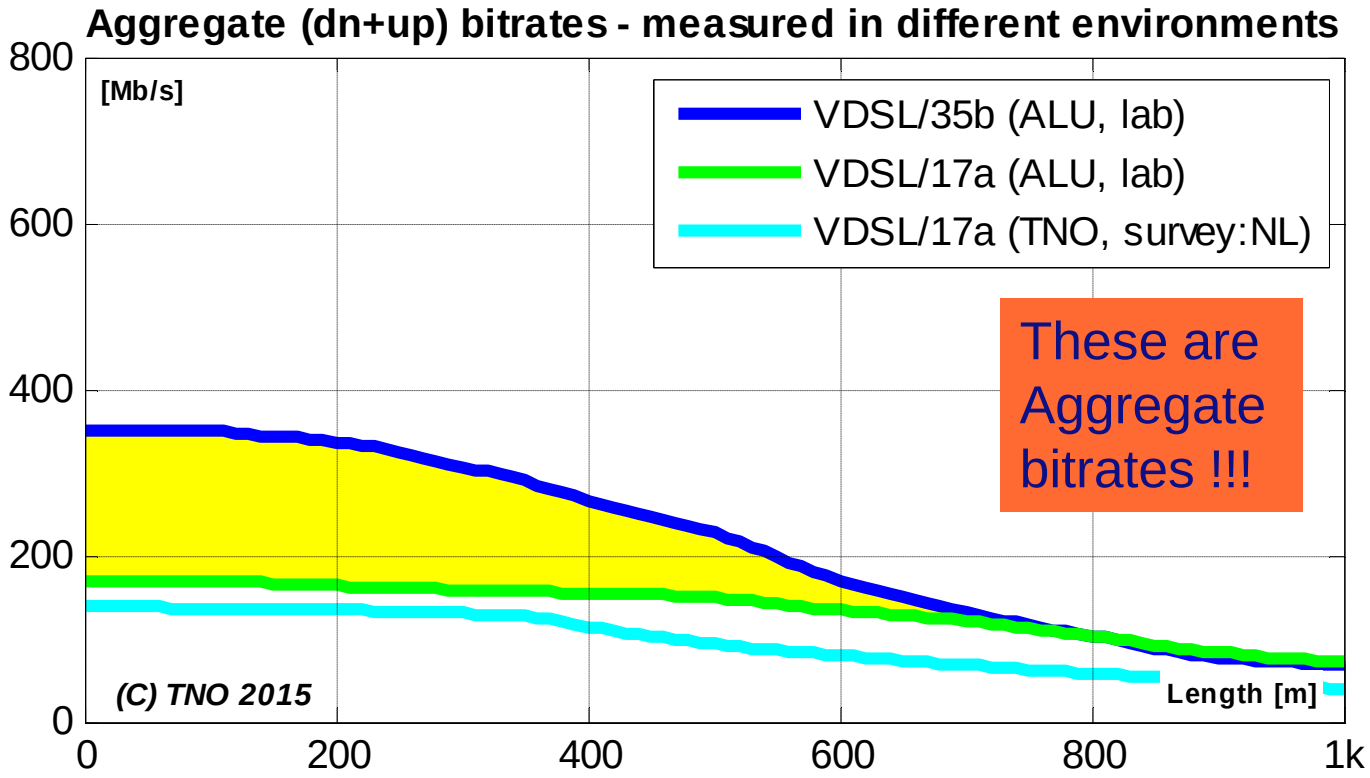
1. Reach-extended G.fast: attainable VDSL bitrates



Measured bitrates for VDSL/35b

- VDSL/35b lab rates measured by ALU
- VDSL/17a lab rates measured by ALU

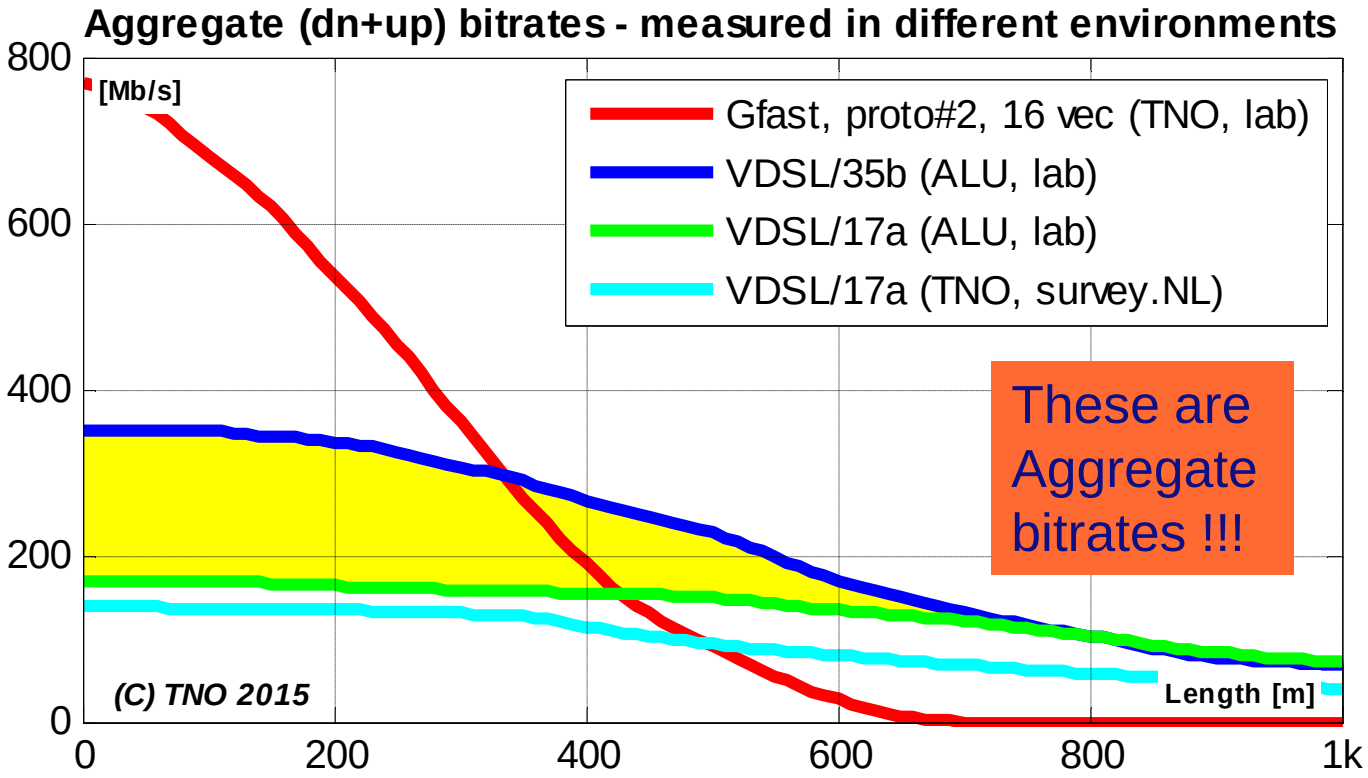
1. Reach-extended G.fast: attainable VDSL bitrates



Measured bitrates for VDSL/35b

- VDSL/35b lab rates measured by ALU
- VDSL/17a lab rates measured by ALU
- VDSL/17a field rates based on 180k operational lines, variety of cables
- VDSL/17a field rates indicate how lab results may scale to field results
- Lab rates above 350m may be too optimistic compared to field rates

1. Reach-extended G.fast: attainable bitrates



Measured bitrates for G.fast and VDSL/35b

- G.fast lab rates easily outperform VDSL/35b lab rates on loops up to ~350m
- But there is no fundamental need to underperform VDSL/35b above ~350m
- VDSL/17a field rates indicate how lab results may scale to field results
- Lab rates above 350m may be too optimistic compared to field rates (G.fast & VDSL)

1. Reach extended G.fast – implications

- G.fast reach can improve on longer loops
  - Increase G.fast transmit power, upto VDSL levels
  - Lowering the noise floor (e.g. linearity)
  - Changing gap time between up & downstream slots
  - Maybe optimization of other design parameters as well
- G.fast has to support larger vector groups
  - Vendors: 96 is doable, larger groups are not excluded
  - The computational complexity of 384 ports VDSL/17a is comparable with 192 ports G.FAST vectoring (*Lantic/INTEL @ G.fast summit 2015, H.P Trost*)
  - Note: 192 bonded VDSL/35b ports still mean 96 subscribers
- G.fast gains from the simplification of powering
  - Reverse powering no longer needed in cabinets
  - Local powering allows for more CPU power

"Reach extended G.fast" has gained full awareness from industry

2. Copper backhauling

Typical use case: dense city areas

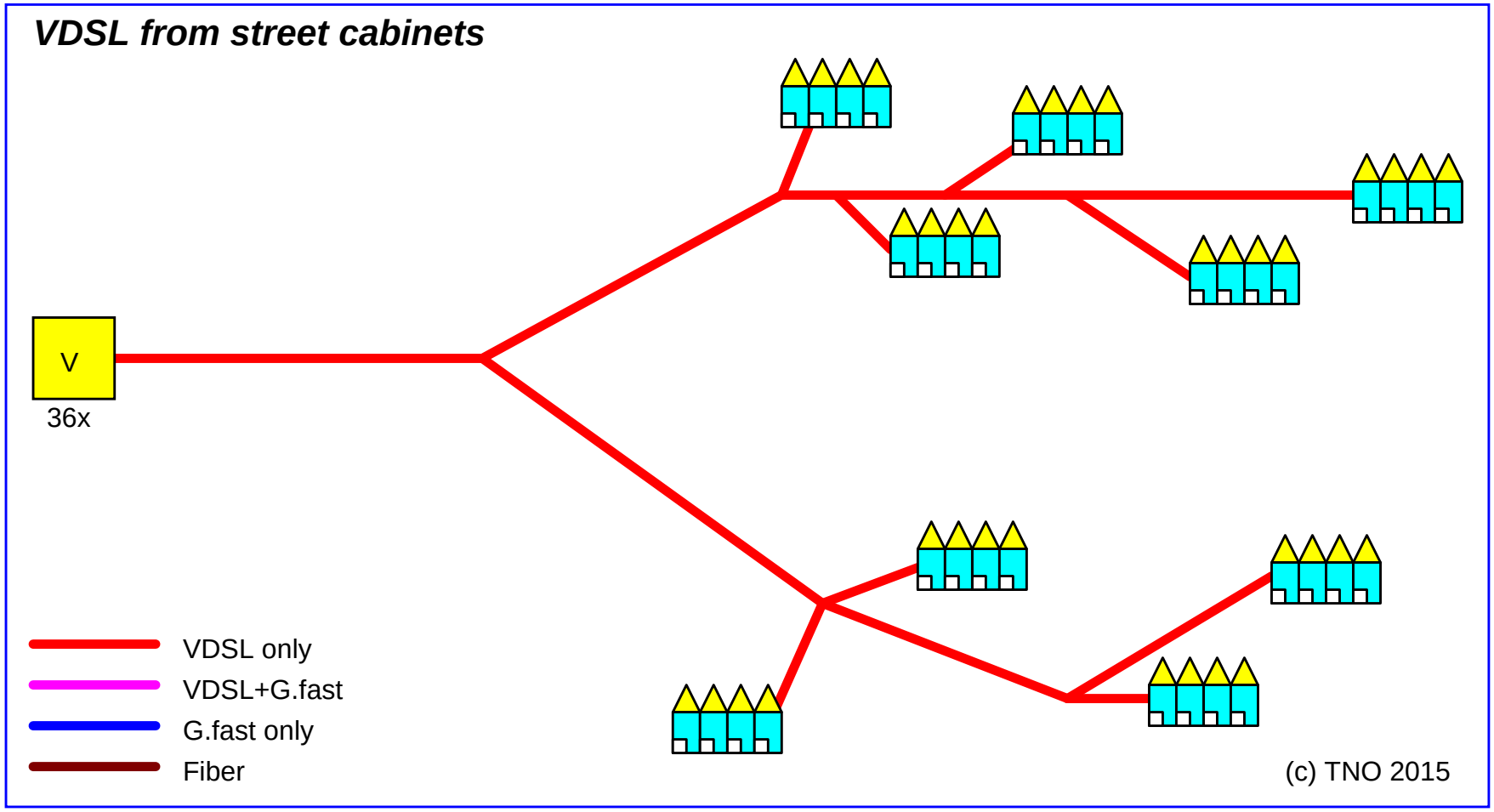
- What do we mean with 800Mb/s?
  - Sustainable bitrate?
  - Peak rate?
  - “Advertisement rate”, similar to cable operators?

- What about delivering the following service:
  - 100 Mb/s Sustainable (e.g. 4 video streams simultaneously)
  - 800 Mb/s Peak (occasional download of files)

- And what about migrating to this …
  - without digging for more fiber to backhaul this?
  - without digging for a power line?
  - Just a simple hole in the ground for some new equipment?

Yes – that is what copper backhauling may offer

2. Copper backhauling

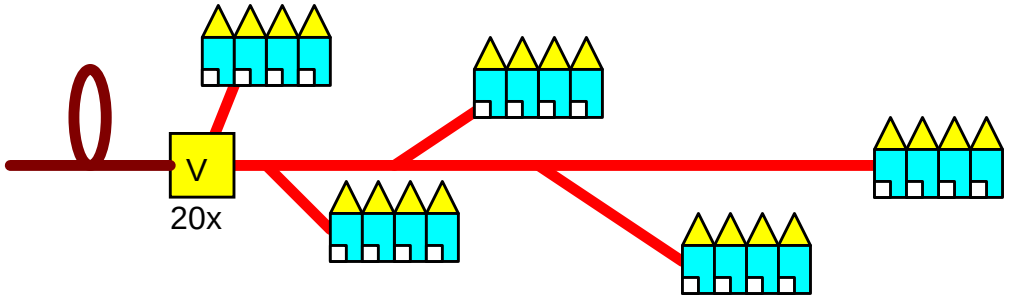


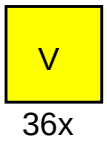
Example of present situation in dense city areas

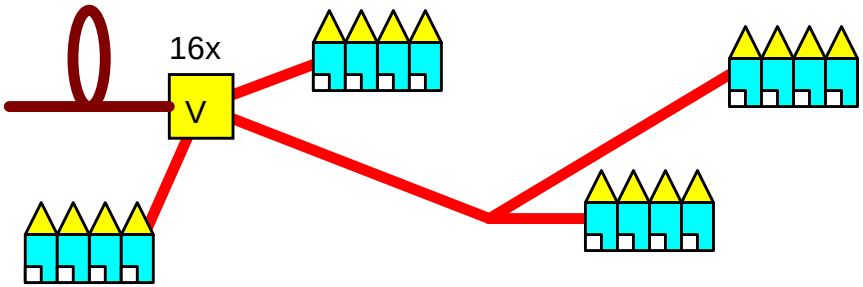
2. Copper backhauling

VDSL closer to customer
"fiber backhauling"

"mini DSLAMs"





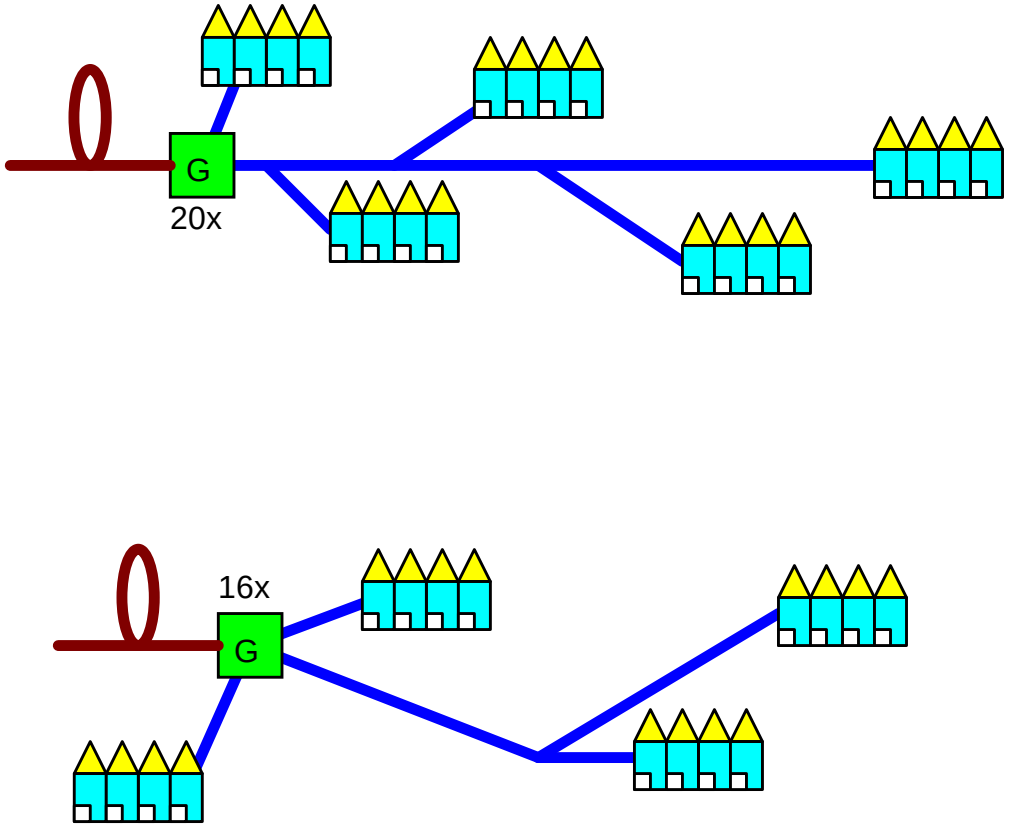


VDSL only
VDSL+G.fast
G.fast only
Fiber

Possible migration to higher bitrates

2. Copper backhauling

G.fast closer to customer
"fiber backhauling"



V
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VDSL only
VDSL+G.fast
G.fast only
Fiber

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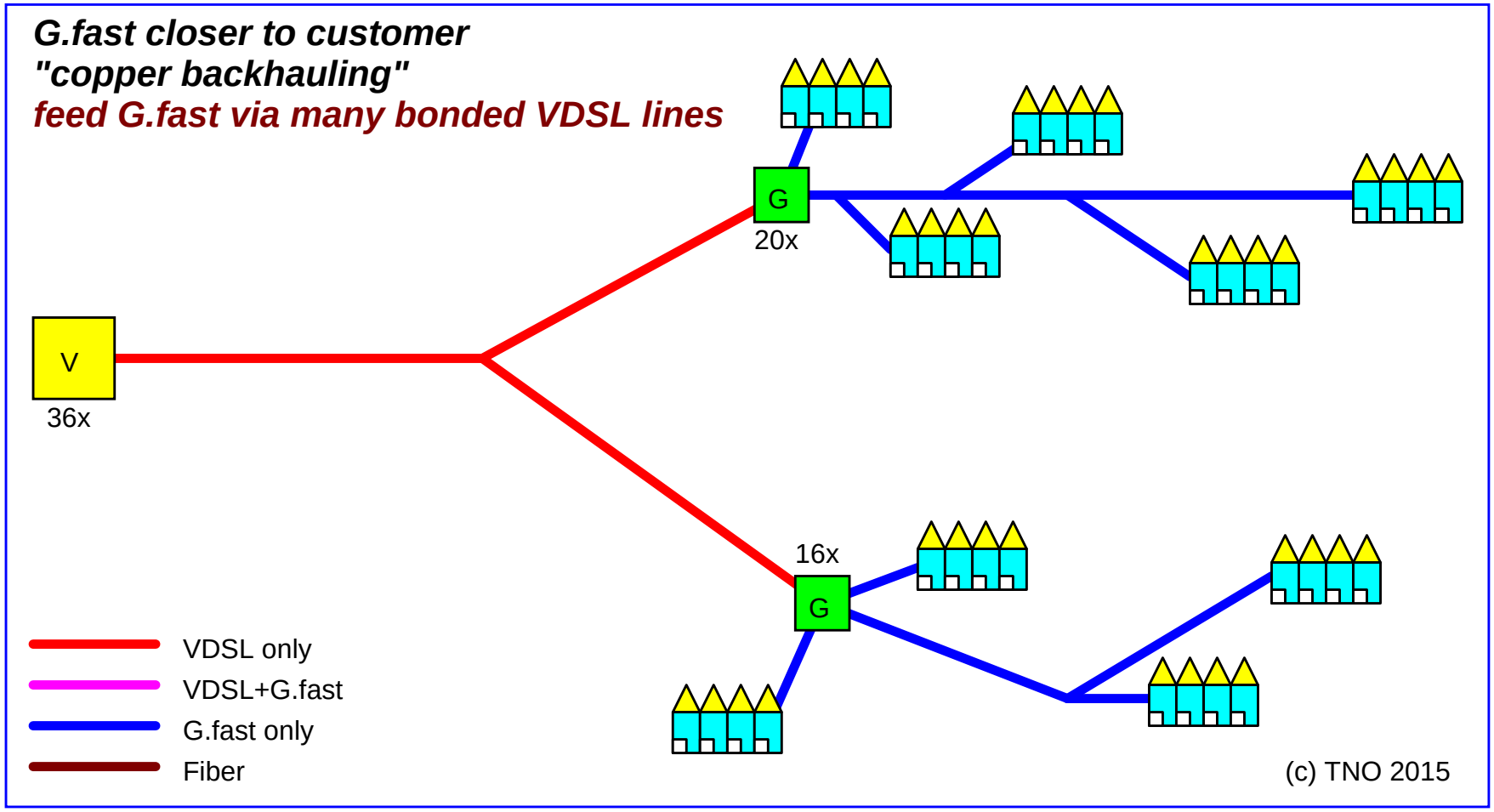
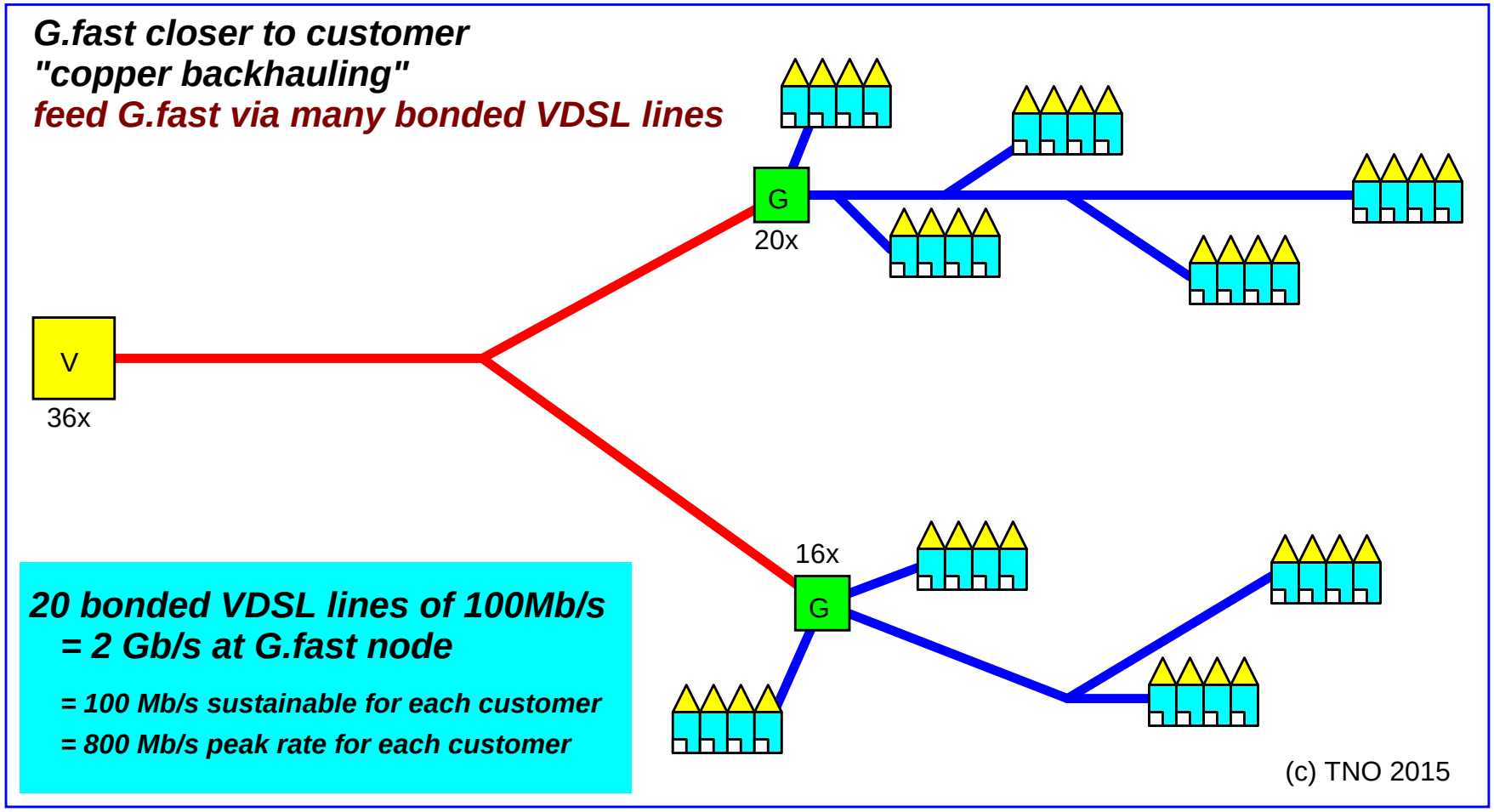
Alternative migration to even higher bitrates

2. Copper backhauling



Similar migration, but far more cost-effective

2. Copper backhauling



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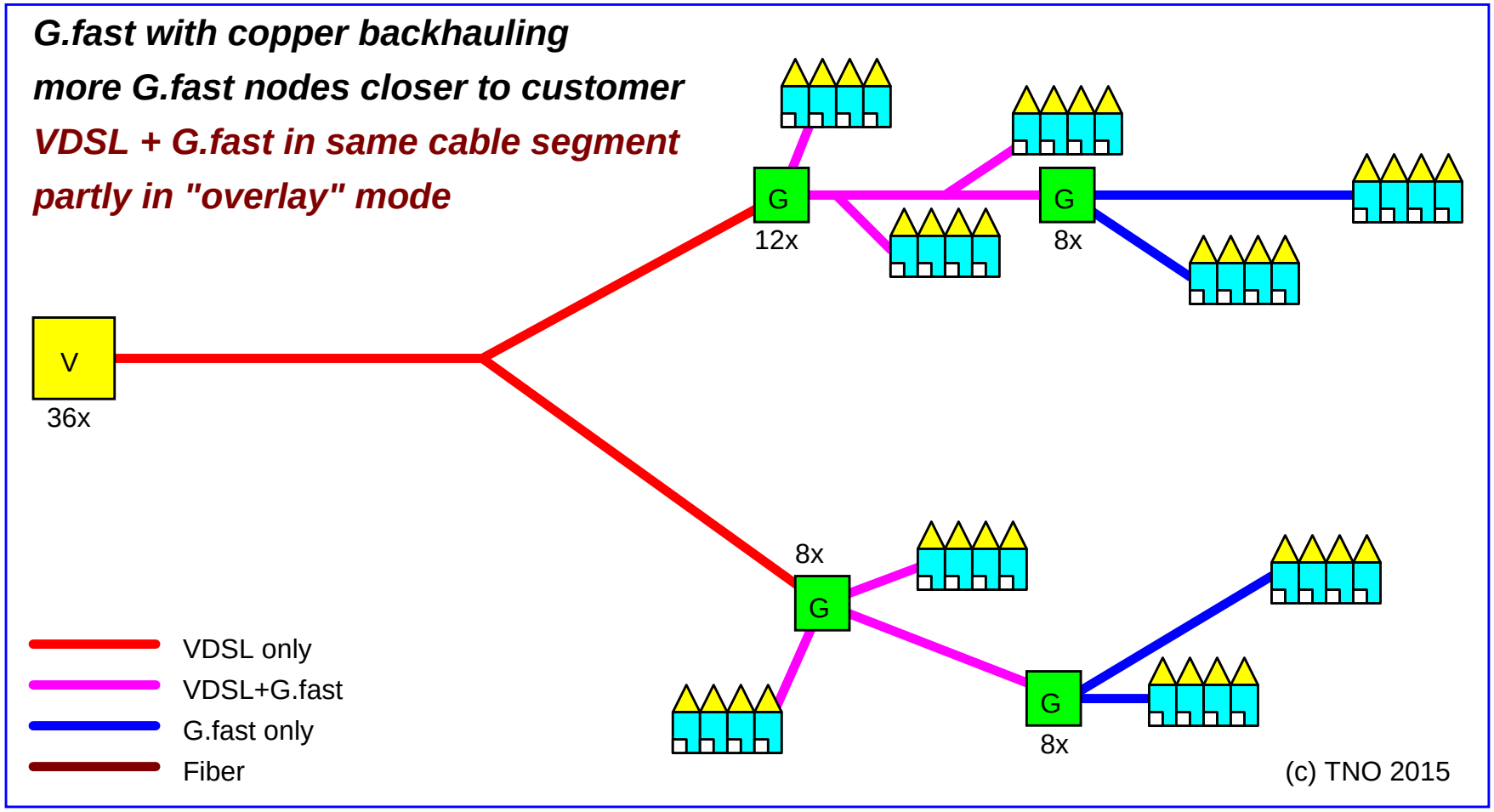
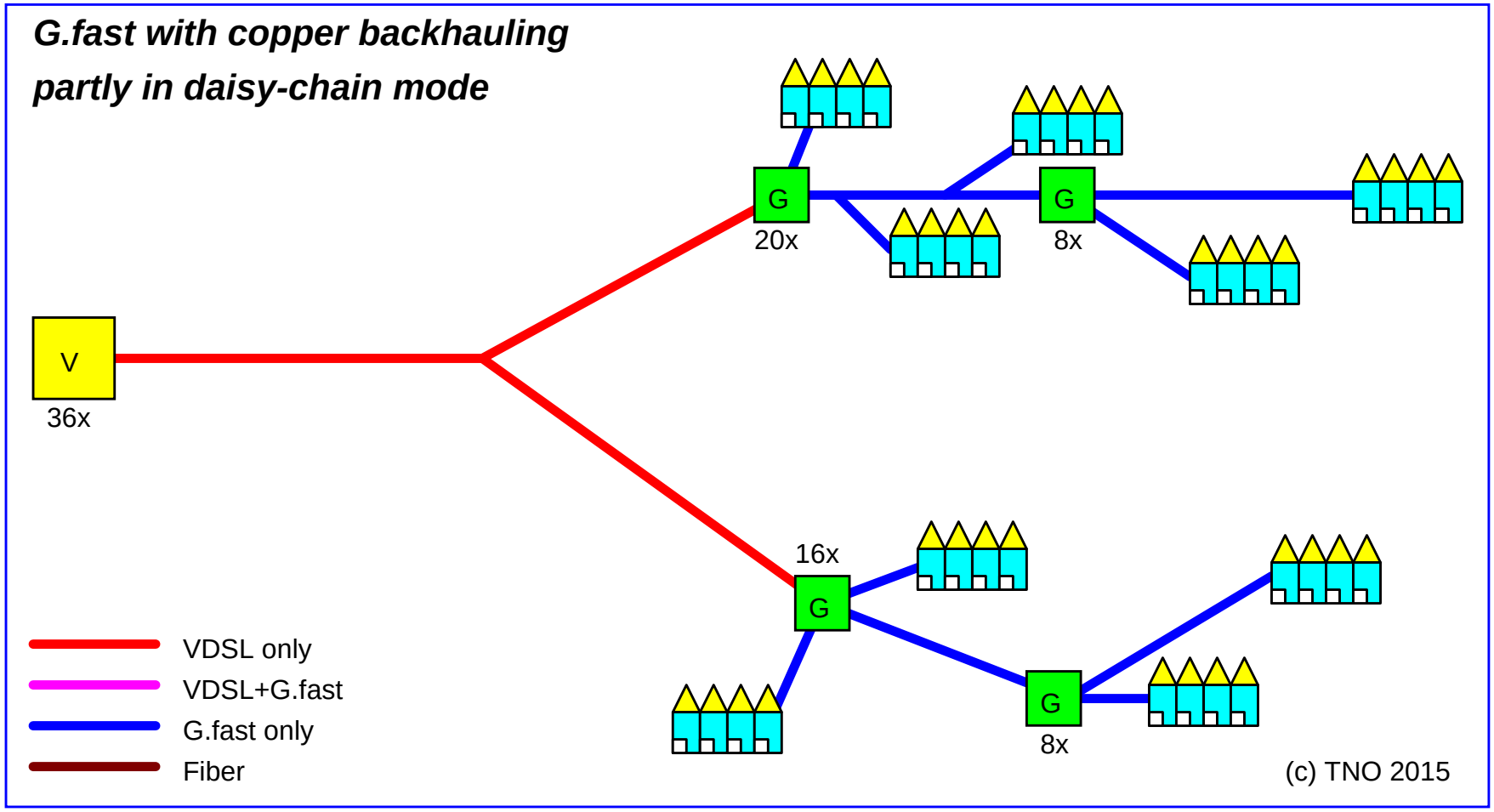


This offer higher rates to distant customers as well

2. Copper backhauling



Similar migration, but now “daisy chained”

2. Copper backhauling – some application questions

Scenario questions

- How much do we gain with CBH in terms of costs and installation time
- Where and how often is CBH beneficial
- Does “daisy chaining” make sense in practice
- What are reasonable ratios for statistical multiplexing
- Backhauling via VDSL or via G.fast?

Technical questions

- How about latency, overall startup times, overall robustness, etc.
- Can we upgrade installed VDSL equipment for use as CBH

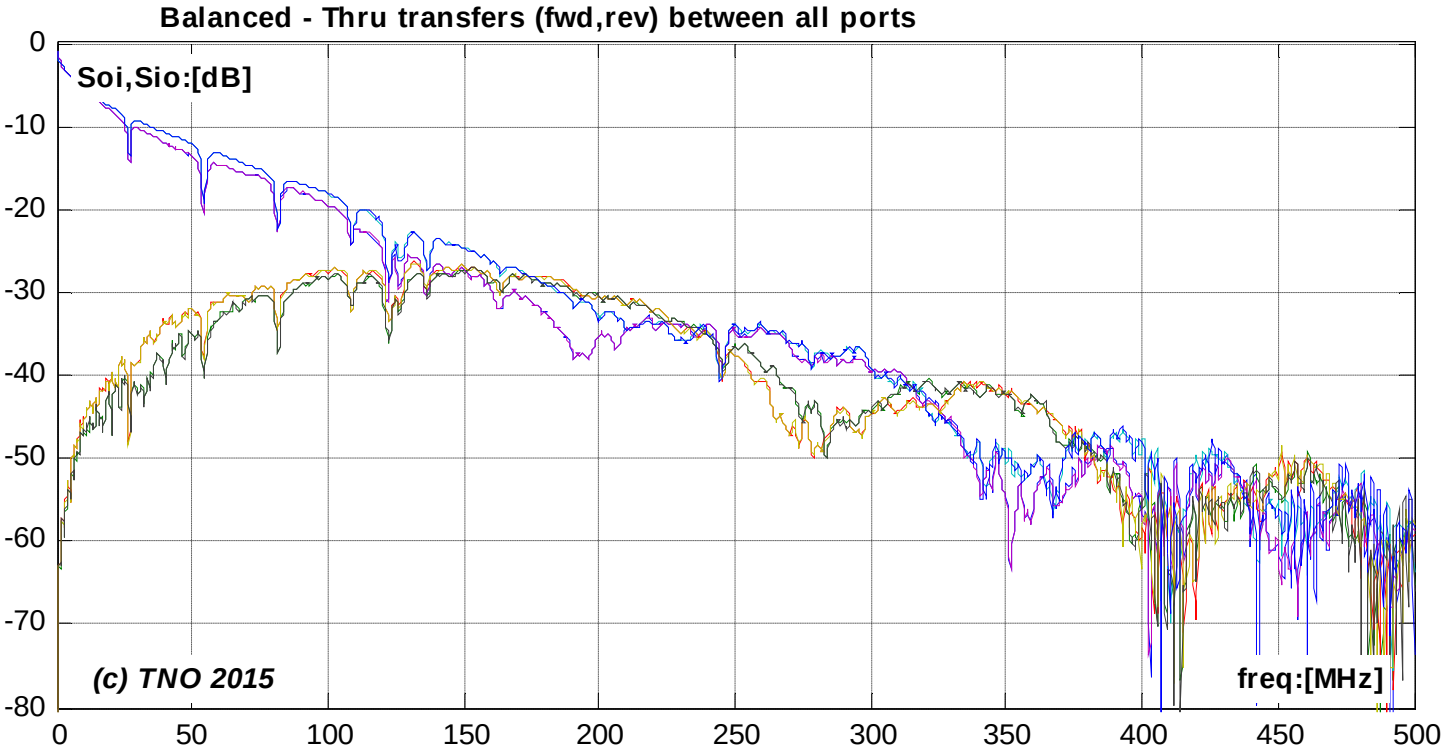
Recommendation

- Start thinking if CBH is to be integrated in your overall roadmap for fiber closer to the customer

3. Next generation G.fast

Broader spectra **à** higher bitrates on shorter loops

- 159MHz, 212 MHz?
- **à** Biggest challenge: coping with high crosstalk environment



(100m, in-quad, KPN access cable)

Vectoring problem: required level of “anti-noise” above transmit signal level

3. Next generation G.fast

Solution: Non linear precoding (*saves noise power*)

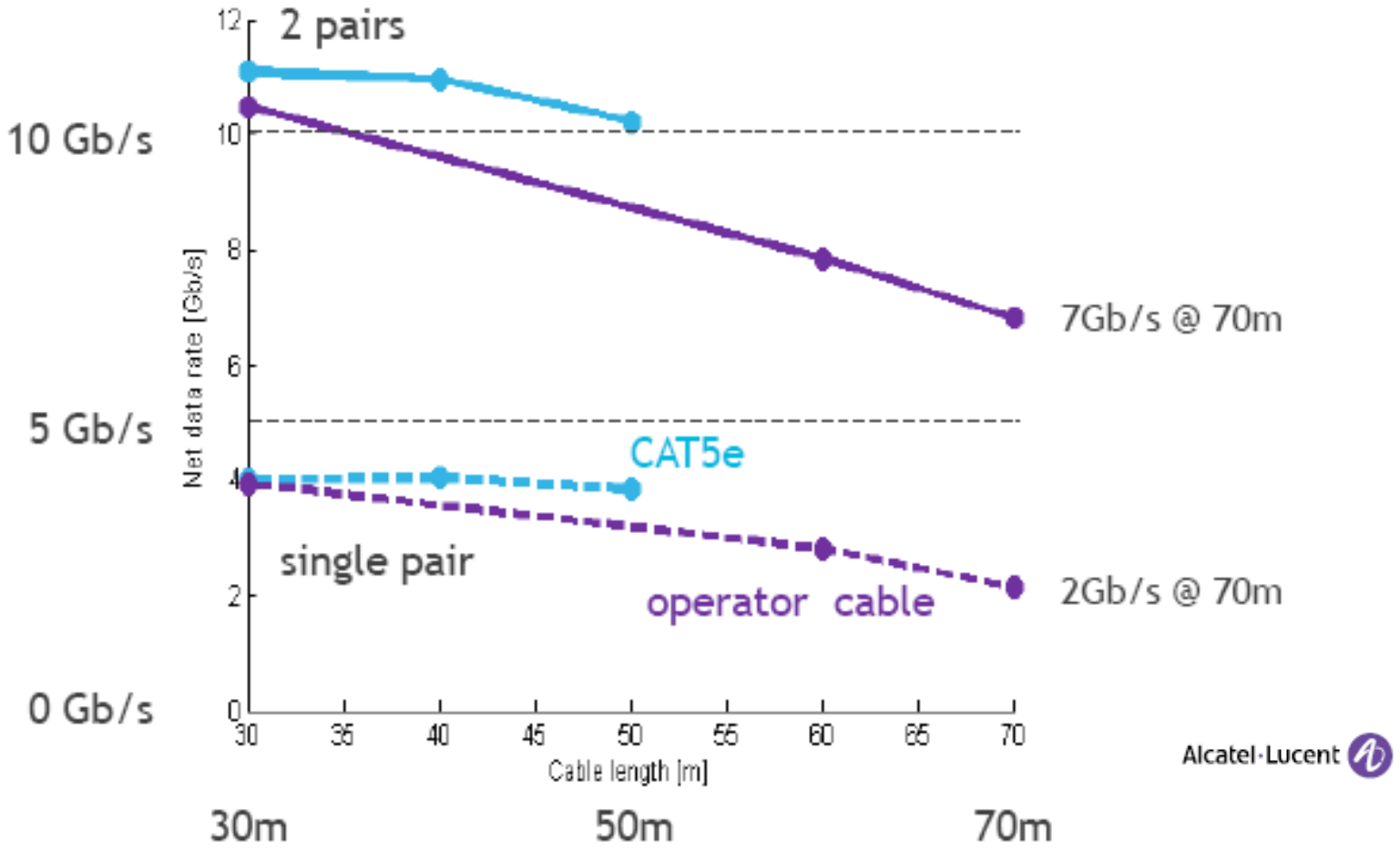
Receive0	= (Signal/IL)	+Noise	no vectoring
Receive1	= (Signal - Noise×IL)/IL	+Noise	linear
Receive2	= (Signal - mod(Noise,*m*)×IL)/IL	+Noise	non-linear
Receive2’	= mod(Receive2, *m*)		

Numerical example (*for IL = 1 = 0dB, and m=5 levels*)						
Signal	0	1	2	3	4	
Noise	7.6312	15.310	15.904	3.737	9.795	
AntiNoise1	-7.6312	-15.310	-15.904	-3.737	-9.795	-Noise
AntiNoise1	-2.6312	-0.310	-0.904	-3.737	-4.795	-mod(Noise,5)
Receive1	0	1	2	3	4	
Receive 2	5	16	17	3	9	

3. Next generation G.fast - implications

Today unclear how much can be gained with G.fast up to 212 MHz.

4. Beyond G.fast (up to 500MHz?)



Potential Use case:

- FTTH, 1 to 3 Gb/s, **symmetrical**,
- from street into the homes via copper, to save installation costs


TNO