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Conference Paper

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VDSL and G.fast Vectoring and the impact on VULA

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Main Tracks: Infrastructure Layer, Internet Policy and Governance

Research Question: Which impact have the coming up technologies VDSL vectoring and G.fast Vectoring on the regulation of VULA

Remarks on Methodology: Technology and network structure analysis, impact analysis on EC Market 4 and 5

Abstract

VDSL and G.fast Vectoring are transmission technologies over copper access line pairs enabling the transmission of higher bandwidth to the end customers, but harm the infrastructure based competition using physical unbundled copper lines. Thus regulators have to decide between infrastructure based competition of physical unbundling against earlier broadband rollout meeting the DAE goals in time and bandwidth, while pure fibre based broadband networks will require more time and investment for serving whole areas, but then provide higher bandwidth. Thus VDSL and G.fast Vectoring each are an interim solution. This paper highlights the benefits of such solution and the regulatory challenges and options being faced. The Virtual Unbundled Local Access (VULA) is one regulatory tool forming a compromise between the advantages of physical unbundling and the need to early satisfy higher bandwidth supply targets.

Keywords: *Access regulation, market 4, VDSL, Vectoring, G.fast, VULA, …*

Introduction

VDSL and G.fast are technologies allowing to transmit higher bandwidth over copper pairs as access lines of a fixed telecommunication network compared to a traditional DSL copper access line network between end customer and local exchange. This is achieved by using new transmission protocols with higher frequencies along the lines. These higher frequencies only can be transmitted over shorter copper loops than before due to increased attenuation. Therefore the access line will be substituted by a fibre line which is more or less invariant regarding bandwidth and distance, at least for the first network segment from the local exchange to the end customer. This significantly saves investment compared to a full fibre access network (FTTH). Therefore a natural migration path towards higher bandwidth per end customer might be from full copper loop to FTTC, then FTTS, then FTTB and finally FTTH (Figure 1). The copper subloops remain in use, but now over a shorter copper loop length. They are terminated in DSLAMs (Digital Subscriber Line Access Multiplexers) hosted in Street Cabinets (FTTC, Fibre to the Curb)) or manholes (FTTS, Fíbre to the Street) or in the basements of the customer premises (FTTB, Fibre to the Building).

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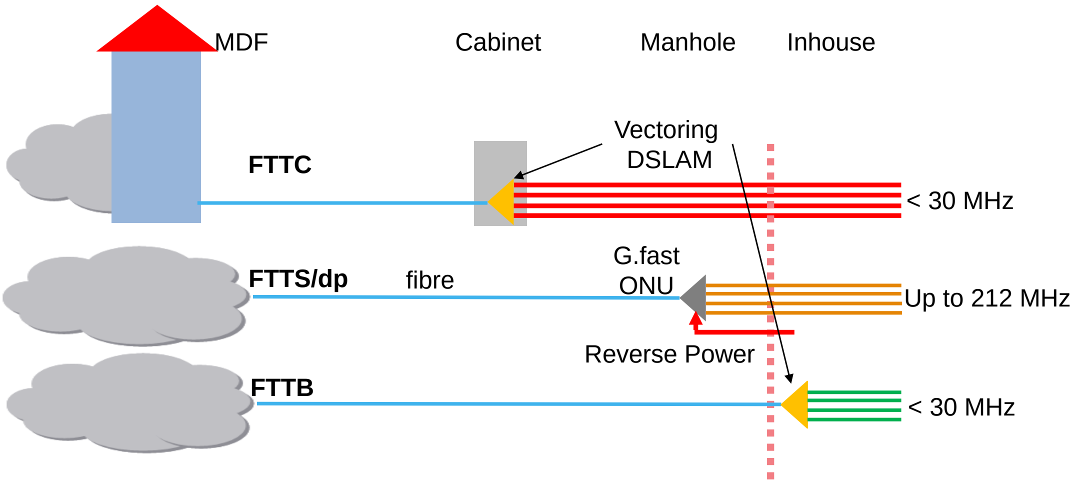
Figure 1: Migration path for broadband roll out still using shorter and shorter copper access lines



Source: WIK

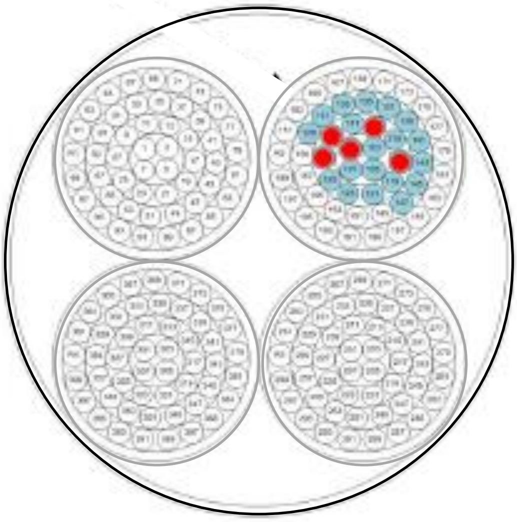
The higher the bandwidth to be transmitted the shorter the remaining copper loop connecting the end customer might be. Nevertheless, even with shorter copper loop length the signal strength and transmittable bandwidth decreases with the increasing access line length. VDSL on a single copper pair may transmit up to 100 Mbit/s downstream over the first 300m and then decrease in bandwidth down to approximately 50 Mbit/s over 800 m and 30 Mbit/s over 1.200 m (Figure 3). VDSL uses a frequency spectrum of typically up to 17,6 or 30 MHz, depending on the profile used. G.fast uses a frequency spectrum of up to 212 MHz and thus achieves a higher bandwidth of approximately 1 Gbit/s (both, up- and downstream) (Figure 5). But the admitted line lengths for capacities higher than VDSL are with G.fast below 300m. Thus while VDSL may be implemented at a FTTC network level G.fast is better suited to FTTS/ FTTdp and FTTB topologies, ending the fibre closer to the end customer and therefore requiring more investment for the fibre roll out, but still spending significantly less than for an FFTH topology.

Both technologies allow to better meeting the national and EU Digital Agenda bandwidth goals of 30 or even more Mbit/s downstream for all end customers and also speeding up roll out and decreasing the required investment significantly compared to pure FTTB/ FTTH deployment. FTTS may be another step of offering higher bandwidth before requiring full fibre speed. FTTB/H on the other hand promises more future-proof bandwidth scalability and operational advantages but requires considerably higher investments. Both technologies therefore are interim solutions for speeding up broadband coverage and enabling traditional fixed line operators to compete with cable-TV infrastructures before FTTH is rolled out. This paper discusses improvements achievable by VDSL and G.fast Vectoring over standard VDSL and G.fast technologies and compares the required investments with a nationwide FTTH deployment. In addition this paper addresses some regulatory challenges in the European regulatory environment, including the European Commission's draft regulation on Single Market/ Connected Continent [EC 2013].

Vectoring advantages in transmission behavior

While the transmission of legacy protocols (like POTS/ ISDN, … ADSL 2+) can be continued mostly unaffected if the new transmission protocols do not interfere with the old protocols by excluding the frequency spectrum of the old protocols from the spectrum of the new ones, the transmission of several signals of VDSL or G.fast on parallel copper pairs of the same copper pair bundle (Figure 2) results in significant interference between the copper pairs since they operate in the same frequency spectrum. This crosstalk may reduce the bandwidth gain of the new technologies to a minimum. The influence of the neighboring access lines in a cable may be significantly reduced by using STP cables (Shielded Twisted Pair), but the access line networks of the incumbent operators typically consist of unshielded (UTP) cables.

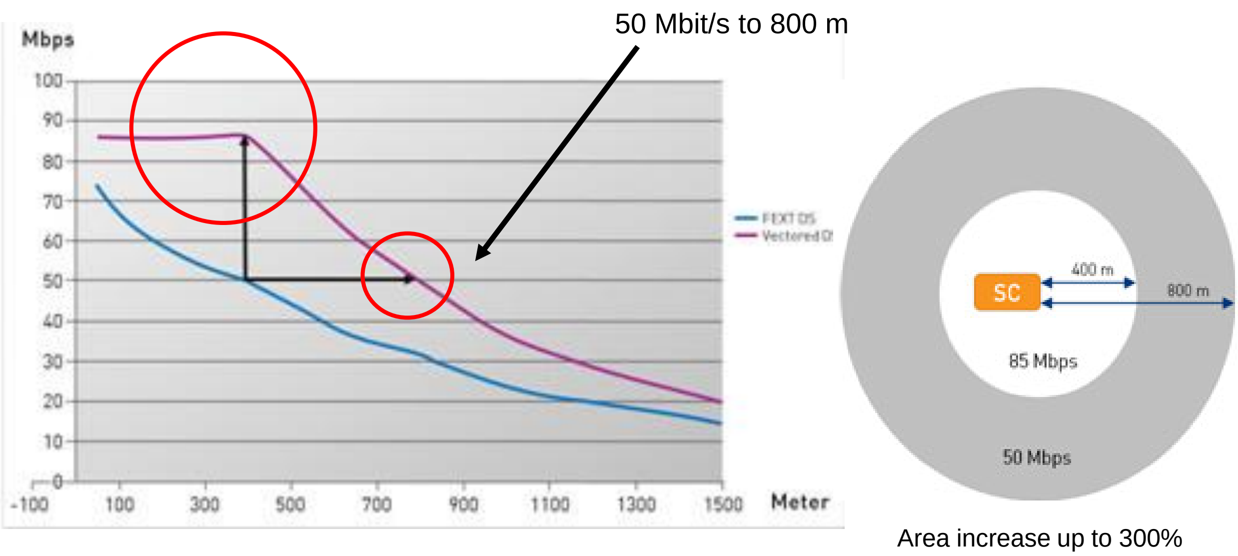
Figure 2: Copper cable with four cable binders of copper pairs



Source: Alcatel Lucent [ALU 2011]

With upcoming increased real time process computing power the Vectoring methodology came up allowing to correct the crosstalk damage on a user signal by estimating the crosstalk impact of each neighboring copper pair of a copper pair bundle on the user signal and subtracting it. This procedure requires knowledge of all signals transmitted in each copper pair bundle. Subtracting the crosstalk effects reestablishes the original signal to a large extent thus strongly improving signal quality. As a result data may be transmitted over copper pairs with higher bandwidth or over longer distances. This improvement increases the coverage area and thus the connectable end customers in a nonlinear manner (by the square of improvement of distance (Figure 3) for VDSL Vectoring, Figure 5 for G.fast).

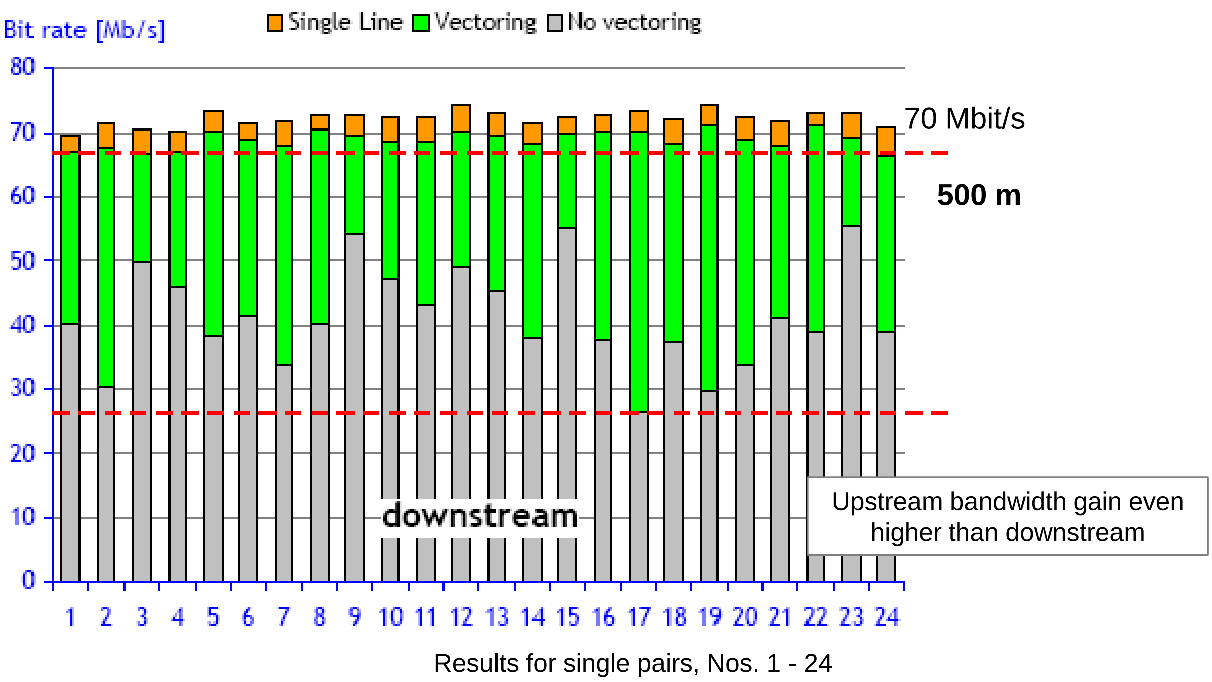
Figure 3: VDSL Vectoring increases bandwidth, distance and coverage



Source: ECI [Can 2012]

Without vectoring the achievable bandwidth varies noticeably between the different copper pairs of a bundle when all pairs are active (grey pillars in Figure 4, for VDSL Vectoring, G.fast Vectoring operates analogue). With all lines in operation the achievable bandwidth is also much lower compared to the bandwidth when operating just the single copper pair without any active signals and hence crosstalk from other lines (orange pillars). VDSL Vectoring improves the transmittable bandwidth per copper pair significantly (green pillars), close to the optimum (orange), as demonstrated in Figure 4 as a result of field trials over a distance of approximately 500 m.

Figure 4: VDSL Vectoring increases bandwidth of all copper pairs towards a comparable high level



Source: Alcatel Lucent [ALU 2011]

Under vectoring customers also receive roughly equal performance on their copper line. Given that the negative effects of crosstalk increase with the number of active lines vectoring brings the benefit of enabling fully loaded (100%) cable bundles with high bandwidth customers. Without vectoring fully loaded cable bundles suffer from very high signal degradation that effectively cap the penetration at a level below 100%.

Furthermore, the minimum bandwidth in an access cable (red broken line) can be more than doubled by vectoring and this relation is even better in the upstream direction.

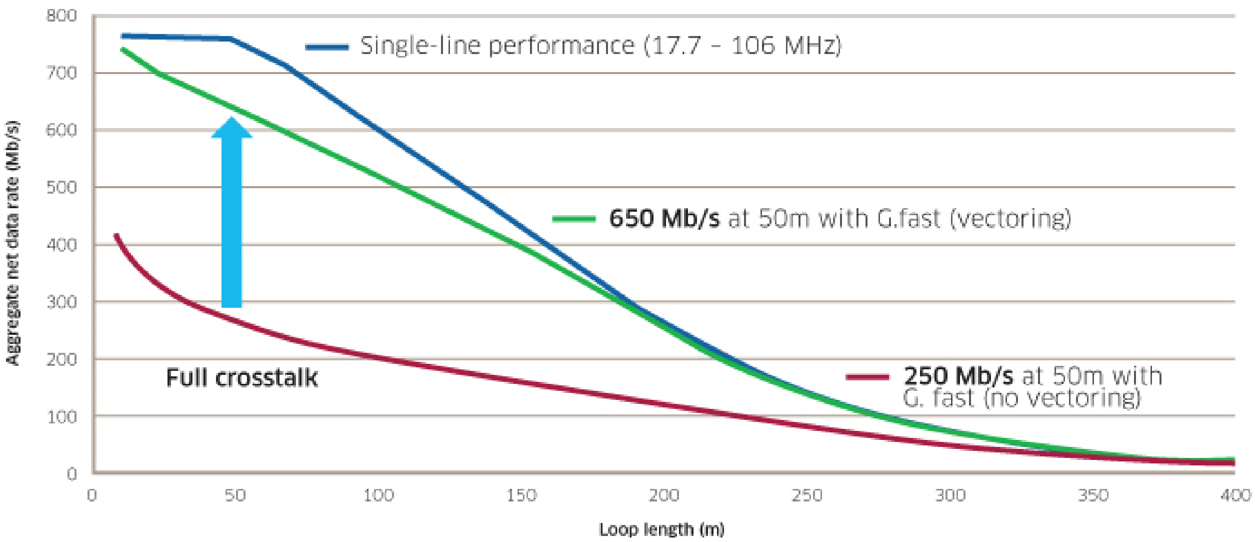
In summary, compared to a standard FTTC VDSL solution VDSL Vectoring

- Increases (doubles) bandwidth and decreases asymmetry between up- and downstream,
- Allows to use access cables by 100% high bandwidth customers,
- Enables comparable bandwidth for all customers of comparable distance from street cabinet and increases the minimum bandwidth in the network significantly, improves the predictability of achievable bandwidth and
- Increases the reach per access line, e.g. for 50 Mbit/s, resulting in over proportional increase of end customer coverage (πr^2).

For further details see [Plu 2013a].

The capabilities of G.fast and the application of a vectoring method (sometimes called Vectoring V.2 as another release of the vectoring principles) also result in similar capacity improvement over distance, doubling the capacity of crosstalk affected lines and coming close to the single line performance (Figure 5). Thus the summarize advantages for VDSL Vectoring also hold for G.fast vectoring in its different bandwidth/ distance scale.

Figure 5: Bandwidth improvement due to Vectoring in G.fast transmission



Source: [ALU 2013]

(Figure 5 only refers to a transmission of up to 106 MHz and excludes frequencies below 17.7 MHz also, thus does not reflect the full capacity of G.fast, but describes the capacity of the first product roll out which not yet includes the frequencies up to 212 MHz.)

Investment and financial advantages of vectoring

FTTC replaces the feeder copper cable between the MDF (Main Distribution Frame or local exchange) location and the street cabinet with fibre and aggregates the end customer traffic in DSLAMs at the street cabinets. FTTS replaces even more copper, down to the manhole where the G.fast ONU is located. The remaining copper subloops are reused in an FTTC or FTTS environment. Compared to an FTTH topology there is a significant reduction of investment because no civil works are required in the remaining distribution segment. FTTC requires active street cabinets which have to be expanded compared to standard passive cabinets in order to host the DSLAMs. FTTS requires manholes or small cabinets, which typically will be served by electrical power from the end customer side (Reverse Power in Figure 1). Due to the decentralization of the DSLAMs compared to hosting them in the MDF locations the scale effects decrease. In total: Assuming the same average revenues per user in an FTTC or FTTS and an FTTH NGA architecture the profitability of a business case with FTTC respectively FTTS is greater.

Table 1: Comparison of the investment per home connected at 70% penetration in Germany

Cluster	FTTH/P2P	FTTC Vectoring	Delta in %
1	1,440 €	320 €	78%
2	1,650 €	350 €	79%
3	1,740 €	370 €	79%
4	1,780 €	370 €	79%
5	1,840 €	370 €	80%
6	1,940 €	380 €	80%
7	2,010 €	410 €	80%
8	2,180 €	420 €	81%
9	2,230 €	440 €	80%
10	2,410 €	480 €	80%
11	2,440 €	500 €	80%
12	2,480 €	520 €	79%
13	2,560 €	560 €	78%
14	2,640 €	600 €	77%
15	2,650 €	590 €	78%
16	2,710 €	640 €	76%
17	2,670 €	680 €	75%
18	3,030 €	830 €	73%
19	3,410 €	1,020 €	70%
20	4,310 €	1,390 €	68%
Average	2,410 €	560 €	77%

Source: WIK [Jay 2014, also Plu 2014b (English)]]

Table 1 describes the results of a modelling approach for NGA networks in Germany, where MDF areas were grouped and sorted according to their population density in a descending order into 20 clusters of comparable numbers of households (approximately 2.1 million per cluster). The model calculates the investments required for different efficient NGA architectures in a bottom-up LRIC manner, based on exact data of buildings, households and business locations and deploying these networks along the streets to the existing MDF locations (scorched node approach). The investment required for FTTC will be reduced by 70% - 80% compared to FTTH. This table only compares greenfield investment. It has to be kept in mind that FTTC requires renting the copper subloops so cost of subloop unbundling has to be considered in the business case as well. The equipment prices for G.fast are not available yet. The figures for FTTS can be expected between those for FTTC and FTTH. Sprout/ Vanhastel in [ALU 2014] estimate that FTTS might cost more than double of FTTC, remaining significantly below FTTH.

An advantage of FTTC respectively FTTS over FTTH is the time to market. Since no construction is required in the distribution segment between street cabinets and customer premises the deployment time is reduced significantly. This allows the traditional copper based operators to sooner compete with cable-TV network based operators, which use DOCSIS 3.0 for their broadband network offerings. (For further details see [Jay 2014].) FTTS may even allow competing with the upcoming DOCSIS 3.1.

Vectoring disadvantages

The vectoring processor needs to control all signals transmitted over the copper line bundle. All copper pairs have to be connected to the same vectoring processor that computes the crosstalk corrections in real time. For the time being this requires to switch all lines to the same DSLAM. In the future international standards may be established that allow operating different DSLAMs (of different networks operators) on the same copper pair bundle ("node level vectoring”). However, as of today standardization has not yet started so node level vectoring will probably only be available in the longer term.

In order to use the advantages of VDSL or G.fast Vectoring to meet the objective of a relatively quick higher speed broadband coverage (meeting the Digital Agenda bandwidth goals) of the population one has to restrict the number of FTTC operators at the same street cabinet respectively manhole to one operator. This effectively requires changing the regulation for subloop unbundling. Depending on national circumstances this restriction may also affect the local loop unbundling at MDF sites if vectoring is applied to directly connected access lines (without intermediate cabinets). Thus using vectoring results in a remonopolization of the physical infrastructure access to the end customers, so vectoring implies making one step downwards on the infrastructure ladder of investment. While FTTB or FTTH Point-to-Multipoint topologies using GPON also may require stepping back to VULA this can be overcome by real future proof FTTH Point-to-Point topologies allowing for physical fibre LLU with marginal additional cost [Jay 2013].

Even with the improvement of bandwidth and distance the typical copper attenuation behavior cannot be overcome completely, as demonstrated in Figure 3 and Figure 5. Thus the improvement in bandwidth through vectoring still depends on the subloop lengths, which differ from customer to customer and in its average also from country to country. In order to meet the EU DAE bandwidth target of 30 Mbit/s downstream the subloop may not be longer than 1,200 m. Thus the attractivity of vectoring may differ from country to country or even from region to region depending on the subloop length.

Vectoring's bandwidth potential is limited to speeds slightly above 100 Mbit/s (VDSL) even in short subloops, and it cannot support symmetric transmission behavior. G.fast can support symmetry, since upstream and downstream Bandwidth can be allocated according to demand, but the sum of both directions is limited to the limits according to Figure 5 (below 1 Gbit/s). In contrast FTTH typically supports symmetry and does not have this length dependent behavior (at least not in the relevant distances of an access network) and supports bandwidth of 1 – 10 Gbit/s on a single wavelength already today. And fibre capacity capabilities are only starting to be unlocked, while the copper medium is almost at physical limits.

Therefore, vectoring, if deployed, is an interim technology on a path towards full fibre access networks. Vectoring might bridge the period until fibre is deployed everywhere, satisfying the increasing bandwidth demand of the end customers.

Regulatory challenges of Vectoring and Virtual Unbundled Local Access (VULA)

We see four options of regulatory actions a National Regulatory Authority (NRA) can take in order to deal with the vectoring challenge:

1. Incumbent monopoly
2. First mover monopoly
3. Open for competition
    a. Free competition (winner takes all)
    b. Obligations for second mover with regard to future node level vectoring
4. Forbidding vectoring

1. Since the incumbent is the owner of all access network assets one could decide that the incumbent is the only operator allowed to deploy VDSL and (later) G.fast Vectoring equipment at the street cabinets respectively manholes or basements and may be also at the MDF locations. In this case the obligation for Sub Loop Unbundling (SLU) (respectively Local Loop Unbundling (LLU)) would be withdrawn. Such decisions have been made in Belgium because none of the competitors expressed its will to compete on a subloop level. The major disadvantage of this option is the resulting single monopoly which provides no incentives to really improve the access network and increase bandwidth further on. Even the investment in higher quality FTTB/ FTTH access networks may be stopped or delayed. In Belgium this monopoly has therefore been limited to 3 years in order to reevaluate the situation then. In order to allow the competitive operators to access their end customers the incumbent must offer wholesale bitstream access services whose characteristics are as close as possible to those of physical unbundled access. Typically this bitstream, which is handed over to the competitors at or close to the MDF locations is called VULA (Virtual Unbundled Local Access). This VULA may be imposed also where fibre Point-to-Multipoint topologies (GPON) FTTB/ FTTH NGA networks are rolled out, which do not allow physically unbundled access to the access lines at the MDF locations either. It must include the higher bandwidths the incumbent is offering its end customers or even higher bandwidths, too.

2. An alternative option is to grant exclusive rights of using the subloop for VDSL/ G.fast to the first investor who installs VDSL/ G.fast Vectoring at the street cabinet respectively manhole. This (local/ regional) competition may increase the roll out speed of vectoring infrastructure and thus might speed up meeting the Digital Agenda targets. By this way regional or local monopolies for the physical infrastructure may appear. As in the first option a VULA like bitstream must be offered to all other operators enabling them to serve their customers in future. In order to prevent the operators

from stranded investment in planning an civil engineering at the level of a ”winner takes all” competition, the German regulator introduced a Vectoring List where plans and commitments for the vectoring deployment on a street cabinet level are registered in a first come first serve manner. While the stakeholders still discuss details of the list operation by the incumbent, the principle seems successful.

3. The third option is to not regulate the use of the subloop at all. Instead one would rely on market forces and the rationale that a second investor cannot benefit from its additional investment in a VDSL Vectoring DSLAM in a street cabinet or in a G.fast ONU in a manhole, at least not by increasing the bandwidth to the end customers. This would result in local monopolies for individual cabinets or even manholes. Again, this could be accompanied by obliging a VULA-like bitstream so other operators have access. While both of the previous approaches also generate investment security for the investors, in this third approach the risk remains that one of the competitors, e.g. a market dominant operator, destroys the vectoring benefits of the first mover by also installing a VDSL DSLAM or G.fast ONU. This situation may be overcome in the future, when (as a minimum) proprietary node level vectoring becomes available, so if the DSLAMs of one supplier support it (instead of international standards for supplier interoperability). A regulation could be defined that obliges the second mover to use the same supplier and his node level vectoring technology as the first mover.

4. Forbidding vectoring allows continuing with the physical unbundling approach of copper lines as before. If SLU is taken by competitors at all strongly differs from country to country. But then the end customers and operators cannot benefit from the bandwidth increase and the high bandwidth penetration increase vectoring can supply. Thus the next step towards increasing the bandwidth per end customer then would have to be FTTB/H. This result might be appreciated on one hand by policy makers favoring an immediate increase of the speed and footprint of fibre roll out, but on the other hand it also may not be chosen by policy makers in order to increase the bandwidth by a relative lower level for an immediate larger footprint and more or nearly all end customers. Correlated with the targets of the Digital Agenda of Europe (DAE) we observe a high political and public pressure towards a smaller bandwidth increase for a much larger number of end customers. A theoretical variant of this approach forbids the use of vectoring only in those dense populated areas where conditions for fibre based infrastructure roll out are good and may also allow for infrastructure replication. Defining these areas would be an additional regulatory challenge.

A recent study on behalf of BREKO, a German association of fixed broadband network operators, estimated the extent of change in broadband coverage depending on the regulatory decisions, either promoting broadband investment by only some major incumbent operators or enforcing competitive investment by many operators, also guaranteeing investment security [Neu 2013]. While Telekom Germany invests into VDSL vectoring in the denser populated clusters 1 – 12 and thus covering 65% households passed, on one hand because of the already existing FTTC VDSL infrastructure and on the other hand because to better compete with the cable-TV operators, the alternative operators to the largest extent invest in those areas where so far no competition exists, into the clusters 13 – 19 (see Table 1). Thus regulation may induce or reduce the additional broadband coverage of citizens in a country. The study extrapolates three scenarios (Table 2) and their related investment for the years 2014 – 2018 out of the past investment history.

Table 2: Investment in FTTC VDSL Vectoring by alternative operators depending on regulatory framework

		Year 2014 – 2018 [in Bio. €]
▪ Scenario I:	AltNets keep on track („Status quo Scenario")	**3.25**
▪ Scenario II:	AltNets reduce investment due to negative regulatory investment incentives („Pessimistic Scenario")	**1.02**
▪ Scenario III:	Altnets intensify investment due to positive regulatory and investment friendly impulses ("Dynamic Investment Path")	**5.21**

Source: WIK, based on [Neu 2013]

Applying these investments in the WIK NGA cost model results in the number of end customers which can be covered (homes passed) at a penetration rate (homes connected) of 40% by the alternative operators. The results (Table 3) clearly demonstrate the high impact a regulatory framework may have on a countrywide coverage and on achieving EU and national broadband coverage goals.

Table 3: Investment change and impact on coverage depending on regulatory framework

	Investment budget for FTTC/Vectoring	Achievable coverage in Clusters 13-19	Homes passed
Scenario I	3,25 Bio. €	46%	7 Mio.
Scenario II	1,02 Bio. €	14%	2,2 Mio.
Scenario III	5,21 Bio. €	73%	11,2 Mio.

- Area-wide FTTC/Vectoring coverage in clusters 13 to 19 requires 7,1 Bio. € investment
- 15,3 Mio. potential customers (homes passed)
- ∆ of scenarios describe potential impact of regulation

Source: WIK, based on [Neu 2013]

The NRA has to balance the increase in broadband coverage against the advantages of free competition based on physical infrastructure. One element of this decision also is to what extent already existing services provided on the copper LLU may be affected: In Austria all DSL transmission signals have to be removed from the subloops/ local loops, whereas in Germany only all transmission signals using frequencies above 2,2 MHz are affected, which in fact only are VDSL transmissions. This is due to the fact that relevant crosstalk only has to be considered in the same frequency ranges. Thus ADSL 2+ and VDSL Vectoring can coexist if VDSL Vectoring usage is limited to the frequency bands above 2.2MHz, or physically more exact: ADSL 2 + does not affect VDSL Vectoring if VDSL Vectoring only relies on the frequencies above 2.2 MHz, which results in a minor capacity downgrade for VDSL Vectoring. Since the lower frequencies may be relevant for longer subloops this restriction may depend on local circumstances.

Another at least theoretical regulatory challenge may come up if one operator deploys FTTC VDSL Vectoring, while the next is overtaking its competitor by deploying FTTB with VDSL DSLAMs in the basement, thus both operators using the same copper inhouse cables. Of course crosstalk interference in these cases strongly depend on the nature of the inhouse infrastructure (e.g. shielded or unshielded twisted pairs, single star wise cabling vs. many pairs in a common riser cable). If exclusivity is required for the vectoring transmission, who shall get it, the first mover or the operator being on the higher step of the ladder of investment (and who does not have to care about crosstalk). Who has to decide it, the regulator or the building owner as the owner of the inhouse infrastructure? Fortunately the field experiences in Cologne and Munich (Germany) demonstrated no such conflicts so far.

Another challenge ist the regulation of coexistence of VDSL and G.fast Vectoring. Shall the VDSL frequencies below 17,7 or even 30 MHz be excluded from the use by G.fast, taking away longer reaching poorer crosstalk affected frequency spaces (German analogy)? Or shall VDSL Vectoring be switched of if G.fast shall be implemented (Austrian analogy)? As far as local loop exclusivity is already granted for VDSL Vectoring in a cabinet access area this question may not be relevant if the VDSL operator and the G.fast operator are the same. By this the migration towards G.fast will not induce a new shift towards infrastructure competition, but will transfer the access line monopoly.

In those cases where already existing services on physically unbundled copper lines are affected, because the right to use the infrastructure will be withdrawn, migration obligations might help the operators to deal with the upcoming economic damages through migration. The obligations the Austrian NRA RTR made may be a guide:

- If migration is enforced at some cabinets within an MDF area, the complete MDF area may be migrated on demand of the competitor in order to prevent the operation of two parallel access infrastructures within one area.
- The cost of the migration is borne by the incumbent operator.
- The price of the access product remains unchanged if the access line speed is not upgraded.
- The competitor’s frustrated investment (book value of the no longer usable access equipment) has to be refunded by the incumbent.
- The steps of the migration process have to be mutually agreed upon in lines and dates.

Table 4: Countries with an obligation for the SMP-operator for Virtual Unbundling/ Local Bitstream in FTTC/B/H roll out areas in Europe (sorted by date)

Country	NRA	Year	Virtual unbundling obligation in case of …	Local bitstream obligation in the case of …	Consequences for the physical unbundling obligation
UK	Ofcom	2010	FTTC/B/H	-	Non imposition of (physical) unbundling in case of FTTH-GPON
AT	RTR	2010	FTTC/B	-	Release of SLU in case of overlapping coverage
BE	BIPT	2011	-	FTTC	Release of SLU in case of FTTC and VDSL Vectoring
IT	AGCOM	2011	FTTC/B/H	-	Non imposition of (physical) unbundling in case of FTTH-GPON
SK	TÚSR	2012	FTTH	-	Non imposition of (physical) unbundling in case of FTTH-GPON
DK	DBA	2012	FTTC/B	-	no
MA	MCA	2012	FTTC (during migration to FTTC only) FTTH (after ongoing Roll-out)	-	 Non imposition of (physical) unbundling in case of FTTH-GPON
IE	ComReg	2012	-	FTTC/B	Release of SLU in case of FTTC and VDSL Vectoring
AT	RTR	2013	FTTH/B/C; Copper network with vectoring at MDF	-	Non imposition of (physical) unbundling in case of FTTH-GPON Release of SLU in case of FTTC without (s. 2010) and with VDSL Vectoring Release of SLU in case of FTTC and VDSL Vectoring at MDF without LLU demand
DE	BNetzA	2013	FTTC		Release of SLU for frequencies above 2,2 MHz in case of FTTC and VDSL Vectoring

Source: WIK, [Plu 2013b]

Accordingly, there will be cases where operators cannot physically unbundle due to either a) economic reasons, or b) due to network technology (vectoring) or topology (like the Point-to-Multipoint fibre infrastructure often deployed in GPON networks) hindering physical unbundling. If in these cases end customers benefit sooner from higher bandwidth offers. A new regulatory challenge came up in the past, which the European Commission (EC) answered in all notified cases by admitting a VULA (bitstream) product with features close to physical unbundling. This wholesale service "*should be made available at a location close to the end customer premises, similar to LLU,*" and "*should allow product differentiation and innovation similar to LLU and thus give access seekers a sufficient degree of control including the quality of service, over the local connection to the end-user*" [EC 2010].

Table 4 provides an overview of these decisions. Additional details can be found in [BER 2014]. Examples for G.fast do not exist yet, since the technology is not yet ready for implementation by operators.

This position is continued and reconfirmed in the new EC market recommendation [EC 2014a], where the relevant product and services markets for ex ante regulation are proposed. In its explanatory note [EC 2014b] the commission once again states that a VULA can be the appropriate substitute for physical unbundling under the conditions already stated above.

The characteristics of the VULA (bitstream) according to the EC up to today may be summarized as:

- Local
- Service agnostic
- Uncontended product
- Sufficient control of the access connection
- Control of customer premise equipment

Defining a VULA service that meets these requirements is a challenge for the NRAs. A well and detailed defined example may be found in Austria. (For further details see [Plu 2013b].)

The EC proceeds in its 2013 draft proposal on Single Market/ Connected Continent [EC 2013] by defining an European virtual access product offered over NGN at layer 2 (Ethernet), which might replace a national virtual access product. Its hand over points shall be closer to the end customers' premises than the national or regional level. Further network characteristics are:

- Flexible allocation of VLANs
- Service agnostic connectivity, control of download and upload speed
- Security enabling
- Flexible choice of customer premise equipment (CPE) (as long as technically possible)
- Remote access to the CPE
- Multicast functionality (where demanded)

The description also includes features of the business processes, the ancillary services and IT-systems and details the required network description and may be detailed in more depth in future updates.

The ongoing debate on this proposal shall define if this virtual service may be a substitute of the physical unbundling, where it is not feasible due to economic or technical reasons, or if it is an access product which under any circumstances may replace the physical unbundling and as such is the shift away from the regulatory target of infrastructure based competition and the ladder of investment principles at its highest level. The position of the new market recommendation, expressed in the explanatory note [EC 2014b] is clearer in this respect. VULA is accepted as long and if there is not technical or economical alternative to physical unbundling – for SLU, fibre or wavelength.

On one hand the initiative to harmonize access products to the benefits of transnational wholesale access seekers and multinational (virtual) companies (which determine a large share of the European GDP) is welcome. However, the authors remain skeptical if these access products can replace the infrastructure competition Europe experienced up to today. With a decrease in infrastructure competition we expect less broadband penetration growth in the European economy and private households in the medium term.

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