WIK-Consult • Report

Study for ComReg

Technical feasibility of providing wholesale broadband access over a cable TV infrastructure

(EC Market 3)

Authors:

Dr Thomas Plückebaum, WIK-Consult
Helmut Kohl, ContaQ Consulting
Markus Muckhoff, ContaQ Consulting

WIK-Consult GmbH
Rhöndorfer Str. 68
53604 Bad Honnef
Germany

Bad Honnef, February 2016

wik CONSULT

Contents

List of figures and tables

Abbreviations

BE	Best Effort
BSoD	Business Services over Data
BSS	Business Support System
CATV	Cable TV
CCAP	Converged Cable Access Platform
CM	Cable Modem
CMTS	Cable Modem Termination System
CPE	Customer Premise Equipment
DOCSIS	Data Over Cable Service Interface Specification
DVB-C	Digital Video Broadcast-Cable
DVB-T	Digital Video Broadcast-Terrestrial
DS	Downstream
DSID	Data Set Identification
EC	European Commission
EoI	Equivalence of Input
FDM	Frequency Division Multiplex
FTTB	Fibre To The Building
FTTC	Fibre To The Curb; Fibre To The Cabinet
FTTH	Fibre To The Home
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPDR	Internet Protocol Detail Record
L2	Layer 2
MAC	Media Access Control
MDF	Main Distribution Frame
MLD	Multicast Listener Discovery
MPLS	MultiProtocol Label Switching
NGA	Next Generation Access
NGN	Next Generation Network
NRA	National Regulatory Agency

OFDM	Orthogonal Frequency Division Multiplex
OSS	Operating Support System
OTT	Over The Top
QoS	Quality of Service
RF	Radio Frequency
RFoG	Radio Frequency over Glass
rtPS	real-time Polling Service
SDH	Synchronous Digital Hierarchy
SLU	SubLoop Unbundlng
SNMP	Simple Network Management Protocol
TDM	Time Division Multiplex
US	Upstream
UGS	Unsolicited Grant Service
VDSL	Very high bitrate Digital Subscriber Line
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
VoD	Video on Demand
VULA	Virtual Unbundled Local Access
WDM	Wavelength Division Multiplex

1 Introduction

Purpose

The Irish National Regulatory Authority (NRA), the Commission for Communications Regulation (ComReg), is preparing its market analysis of wholesale local access and wholesale central access markets, referred to as Market 3a and 3b (European Commission Recommendation of 9th October 2014, C(2014) 7174 final). These markets include unbundled physical access infrastructure, such as ducts, copper pairs and fibres, but also virtual access products with local handover at the cabinet or Main Distribution Frame (MDF) level (Market 3a) and best-effort bitstream with a handover to the wholesale customers at a more central level (Market 3b). In the explanatory notes accompanying the EC recommendation (SWD(2014) 298), the European Commission recommends that NRAs also assess the existence of any Cable TV (CATV) provider in the market and to what extent they will or can already contribute to these markets and compete with the established providers. This may influence the NRAs' analysis of the market and its conclusions on market dominance.

This study was commissioned in this context and shall investigate the options for wholesale access products that are technically feasible to be offered over a CATV infrastructure based on the Data Over Cable Service Interface Specification (DOCSIS) 3.0 standard.

Scope

This report first introduces the basic technical elements and characteristics necessary to answer the following question: to what extent are CATV networks able to contribute to wholesale Market 3a and 3b? The answer to this will help explain the technical descriptions required to present the product features for wholesale access provision. The introduction also deals with the basic principles of capacity upgrades in CATV networks, including DOCSIS 3.1 (section 1.1).

In principle, many wholesale products are technically feasible within a CATV network's infrastructure. This report identifies which of them can be provided and categorised as physical/passive, virtual/active and non-virtual/active according to the description of the EC explanatory notes (section 2, introduction). In addition, the report assesses to what extent these products could contribute to the wholesale market within the near future. In order to delineate Market 3 from other defined wholesale markets (Market 4: Wholesale high-quality access at a fixed location) and resale, this study includes a brief summary from a CATV network provider's point of view.

This study also examines what a CATV network provider would have to do in relation to its Business and Operating Support System (BSS/OSS) when planning to enter the wholesale market (section 3), and also briefly highlights respective changes in the

network infrastructure of both providers, the wholesale access provider and the wholesale access-seeker (section 4).

Background and context

In the context of the market analysis of wholesale Market 3, as described above, it is necessary to determine if and to what extent other fixed broadband access network providers could contribute to the wholesale market of broadband access, as they also use (independent) network infrastructure assets to produce retail broadband access products. In Ireland, as in many other European countries, a CATV network provider platform exists for fixed broadband access.

Objective/aim

This study does not analyse if wholesale products are already offered by the Irish CATV network operators; instead, it concentrates on the question of whether they have the technical capability to offer these now or in the foreseeable future. This may help determine if the competitive situation of the current wholesale Market 3 will be influenced by new players in the future. If new players are likely to appear in the next regulatory period, this should be considered and evaluated in the NRA's appraisal of market dominance. This study therefore aims to provide guidance for this.

Overview of content

This study first gives an overview of the basic principles of the CATV network infrastructure and its options for capacity enhancement (section 1.1), followed by a list of all possible wholesale products that could, at least in theory, be achieved from a technical point of view (product analysis). It identifies which of these can already be provided and categorises the products in Market 3 into physical/passive, virtual/active and non-virtual/active according to the description in the EC explanatory notes (section 2 of the explanatory notes, introduction). Section 2 of this report considers the potential wholesale products that may be realisable over a CATV network platform, such as:

- Market 3a – physically unbundled ducts (section 2.1.1),
- Market 3a – fibres (section 2.1.2),
- Market 3a – frequency sharing (section 2.1.3),
- Market 3a – Virtual Unbundled Local Access (VULA) (section 2.1.4), and
- Market 3b – Bitstream (section 2.2).

Section 2 also briefly covers high-quality access products (Market 4, section 2.3) and resale (section 2.4) in order to demonstrate common aspects and delineate these markets from each other.

For the more complex products in Market 3a, subsections 2.1.1–2.1.4 then provide analysis on a product-by-product basis to determine to what extent they could contribute to this wholesale market within the near future. For VULA, the study further details the

main criteria such access should have according to the EC explanatory note. It analyses to what extent these criteria can be met by the CATV network equipment using the existing standard DOCSIS 3.0 and provides a preview of the new standard DOCSIS 3.1 (sections 2.1.4.1–2.1.4.7). The results of the wholesale feasibility analysis of Market 3a products are summarised in section 2.1.5.

Wholesale products produced on CATV network infrastructure might have an impact on the operational processes and the OSS supporting them on both sides of the business, namely the wholesale CATV network provider and the wholesale-seeker side. Section 3 includes a high-level OSS impact analysis. The report also compares already existing intercarrier processes in Ireland with those required by a new CATV-based wholesale offer, because the acceptance of new wholesale products may depend on the additional effort required by a wholesale customer to adapt to new processes.

A CATV network that may be used to offer wholesale access services may need to adapt its network topology and components, such as network interconnection and interconnection links. The changes required are analysed (Section 4, network infrastructure analysis), before the report summarises and concludes on which wholesale business offerings are technically and operationally feasible (Section 5).

Target audience

This report is primarily aimed at the Irish NRA and its market analysis staff, to be used within the market analysis process. It may also be used as an accompanying document of ComReg's market definition directed to the European Commission or to the public.

As we are unsure of the technical expertise of the target audience, we have tried to keep the language in this report suitable for laypeople. Technical descriptions are therefore detailed to the degree required for understanding the arguments. The descriptions are interpreted and summarised on a more general level. This study will not detail technology aspects and options beyond this general level of understanding.

1.1 Cable TV and DOCSIS

Traditionally, coaxial CATV networks have been used to broadcast analogue radio and TV signals from a central headend down to the end-customers. The coaxial cable medium was chosen because of its suitable transmission behaviour for high-frequency signals. For downstream broadcast signal distribution, one common cable string (tree structure) design has been and still is ideal and efficient. For longer reach, such string requires intermediate signal reamplification or regeneration. Such infrastructure is called shared medium. Everybody connected to it can easily select the appropriate broadcast service.

When competition for traditional telecommunication services (telephony, data) arose, there was soon demand to use these CATV networks as an additional transmission

medium for intermodal competition. According to its capacity of transmitting signals ranging from several hundred to some thousand MHz, it was able to carry additional telecommunication services.

For this purpose, frequency space at both ends of the frequency band, typically framing the existing TV and radio channels, was defined in the DOCSIS standard for data communication use. DOCSIS allows for downstream data communication in the upper frequency band and also enables upstream communication in the lower frequency band. To enable upstream communication, the CATV network had to be upgraded:

- all amplifiers had to be upgraded regarding the transmission direction (upstream amplifying was also required),
- some frequency filters had to be added in order to separate data from TV and radio bands, and
- the TV and radio channels had to be reorganised to host those channels that had to be removed from the bands now assigned for data communication, if channels had to be removed at all.

A new network component is required to organise and administrate the bidirectional communication – allowing end-user access to the common upstream channel for only one end-customer at a time per channel – and address the downstream information to the end-customer to which the traffic is dedicated. This system is called the Cable Modem Termination System (CMTS).

At the end-customer sites, a new cable modem now interacts with the CMTS, announcing upstream communication demand and picking the downstream end-customer messages from the downstream broadcast channel.

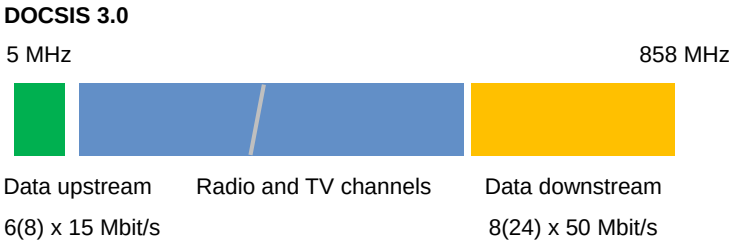
DOCSIS as a bidirectional communication standard on coaxial CATV networks organises the side channels for bidirectional communication; however, it does not deal with the radio and TV channel frequency space in between (see Figure 1-1).[1] Because of the anticipated communication behaviour of residential customers, all DOCSIS systems have been designed for asymmetric communication, giving upstream capacity of approximately 10% of the downstream capacity. This is inherent in the frequency spaces allocated.

DOCSIS 3.0 is the state-of-the-art release implemented today. It typically bundles up to six upstream communication channels with 15 Mbit/s[2] each to 90 Mbit/s upstream and eight channels with 50 Mbit/s each downstream to 400 Mbit/s.

1 Although most operators organise the frequency distribution as described here, the data communication channels could also be included somewhere in the radio and TV channels, but this does not change the principles discussed.

2 WIK assumes an average case of 3.2 MHz channel width with QAM64 coding, but there are also solutions with 6.4 MHz channel width, QAM64 coding and consequently 30 Mbit/s. The upper limit for upstream are eight upstream channels, each transporting 30 Mbit/s upstream, totalling 240 Mbit/s. WIK

Figure 1-1: DOCSIS 3.0 frequency use and data communication capacity allocation



Source: WIK

There are several options to increase the bidirectional data (and Voice over Internet Protocol (VoIP)) communication:

1. Use more of the already designed data communication channels in DOCSIS 3.0,
2. Reduce the frequency space for radio and TV channels,
3. Decrease the number of end-customers sharing the coaxial cable segment, or
4. Define (and implement) the use of a wider frequency range than the 860 MHz defined today.

The following provides further description of the above options.

1. While upstream communication could be expanded by another two channels to 120 Mbit/s, there is still much more space for downstream capacity, going up to 24 channels, totalling a maximum of 1.2 Gbit/s. Today's configuration already demonstrates that there is much more upstream demand than originally designed for (10%). While the upstream capacity in DOCSIS 3.0 is nearly exhausted (90 of max. 120 Mbit/s (75%) in the typical example above), there would be more space for downstream capacity (only 400 of max. 1,200 Mbit/s (33%) used so far in the typical example above). Keeping the relation of current upstream and downstream traffic, the full use of the upstream capacity (120 Mbit/s) would require a comparable downstream capacity increase of 25% to 600 Mbit/s. This would mean that half of the theoretically designed 1.2 Gbit/s of downstream capacity would remain unused. Upstream traffic demand today is often the limiting factor of using DOCSIS CATV network capacity for data communications.

2. Replacing traditional analogue radio and TV channels with digital channels would allow for higher signal quality and picture resolution with less frequency consumption. This effect of frequency space-saving is also called digital dividend. Because of the

is not aware of any operator having changed and expanded its upstream frequency management like this. (65 MHz - 5 MHz)/6.4 MHz = 9.374 channels, but realistically eight channels remain due to interferences and the non-linear characteristics of the spectrum.

fixed upper frequency of the CATV network (i.e. restricted by the amplifier capabilities), additional use of DOCSIS 3.0 downstream channels would require either deleting radio or TV channels or making use of the digital dividend. The latter requires the reorganisation of the program set to keep the program bouquet offered. In any case, the frequency space used by the radio and TV channels has to be reduced. This might mean that the operator has to resolve conflicting interests.

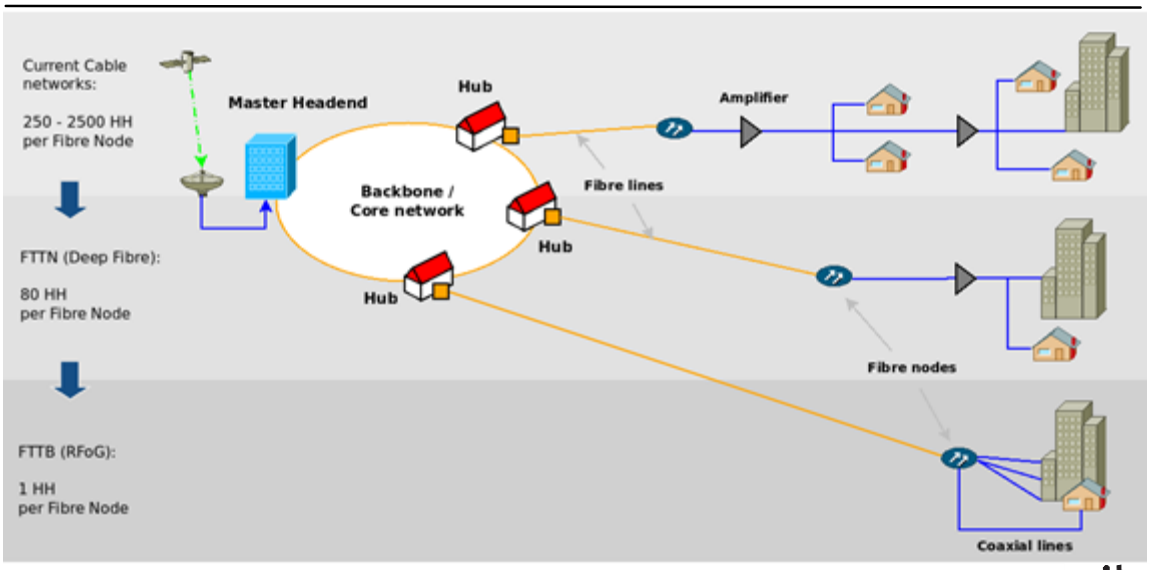
3. The coaxial cable segment is a shared medium, meaning the upstream and downstream customers' communication capacity is always shared by all customers connected to it. If one part of the capacity is dedicated to a customer for a longer time or even permanently, it reduces the remaining capacity for the other end-customers. In the reverse, reducing the number of end-customers connected to a coaxial segment by reducing its size increases the capacity an end-customer can use over time. However, the user will never be able to exceed the total channel bandwidth, so the peak bandwidth is limited.

   Today, the coaxial cable segments are fed by fibre nodes, which are connected to the central sites and to the CMTS located there. These fibre nodes are intermediate systems converting the coaxial cable signals into optical signals and vice versa. Therefore, decreasing the number of customers per coaxial cable segment is typically called fibre node splitting. An existing fibre node is divided into two or more nodes (see also Figure 1-2). It could require additional fibre links to be installed to move the fibre nodes closer to the end-customer locations. Such fibre node distributions are also called "deep fibre". Moving the fibre nodes down to the end-customer premises is called "RFoG" (Radio Frequency over Glass[3]), offering the capacity to one user or a small group of end-customers (multi-dwelling) only. This capacity enhancement requires investment in new fibre nodes[4] and fibre lines, depending on the string or star topology of the coaxial network segment.

3 Any transmission of analogue radio or TV signals over fibre is called RFoG, but here it is used as a synonym for the architecture also.

4 More specifically called RFoG micro nodes or fibre-optic micro nodes.

Figure 1-2: Fibre node splitting



Source: WIK/ContaQ

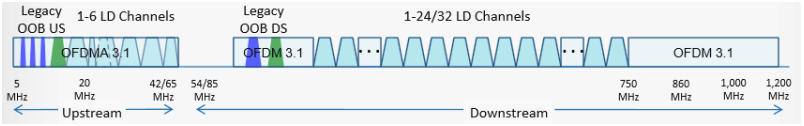
4. State-of-the-art coaxial cables operate up to frequencies of 2.5 GHz. The cable itself would even allow for higher frequencies. A new DOCSIS 3.1 standard has been finalised recently and the first systems on the market now offer frequency space up to 1.2 GHz. A further upgrade is already included in the standard documents. This new standard allows a smooth upgrade of the systems, the CMTS, the cable modems, the reamplifiers and fibre nodes, on a segment-per-segment and customer-per-customer basis. It offers compatibility not only with DOCSIS 3.0 but also with older releases (2.1, 2.0). Most operators now offer products in line with DOCSIS 3.0. Due to the capacity still inherent in release 3.0, there is no need for an immediate upgrade to release 3.1, but it might be an option for future infrastructure use and time for a long-term upgrade strategy. DOCSIS 3.1 will allow for up to 10 Gbit/s shared downstream and 1 Gbit/s upstream capacity (see Figure 1-3). As the end-customer demand tends towards more symmetric communication relations between upstream and downstream or even towards symmetric behaviour, DOCSIS 3.1 is not necessarily the ideal design. WIK does not foresee DOCSIS 3.1 becoming a relevant CATV network reality with significant coverage within the next five years. The study will therefore give an overview but will not provide detailed consideration.

Figure 1-3: DOCSIS 3.1 evolution, frequency use and data communication capacity allocation

- EuroDOCSIS 3.1 migration path

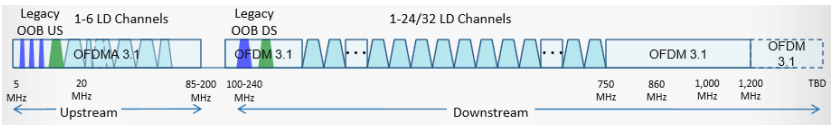
Future

- M-CMTS and CCAP coexist
- DOCSIS 2.0,3.x mix
- Beginning of OFDM



Long Term

- 3.x CCAP only
- Up to 1700 MHz bandwidth
- Reducing 2.0 equipment



- DOCSIS 3.1
  - No channels any longer (DS: 6 – 10 Gbit/s, US: 200 Mbit/s – 1 Gbit/s)
  - **FDM** on Downstream and **Upstream**

Source: Cable Labs, amended by ContaQ/WIK

DOCSIS is not well suited for supporting business customer or high-quality individual end-customer demand: DOCSIS is a data communication standard designed for asymmetrical IP-based communications. There is very limited space for symmetrical communication because the upstream is typically limited to a maximum of 90 Mbit/s. If capacity is exclusively reserved for some end-customers, then this reduces the capacity for the remaining connected customers. The remaining customers then share reduced communication channel capacity with reduced peak capacity, resulting in a poorer burst behaviour and a higher probability of congestion and packet loss, thus having a poorer quality experience.

In order to illustrate this restriction, assume one single business customer is demanding an exclusive 100 Mbit/s access line (like a leased line terminating segment, symmetrical). If one uses DOCSIS 3.0 with today's 90 Mbit/s upstream capacity, it would be impossible to provide this product. Even after upgrading to 120 Mbit/s, the remaining customers would have to share the remaining upstream communication channel with 20 Mbit/s capacity and with a peak bitrate of 20 Mbit/s, which would not satisfy today's customer demand.

Also, communication based on the Layer 2 Ethernet protocol is not part of the standard. There is an optional feature besides the DOCSIS standard without being part of it, called BSoD (Business Services over DOCSIS), which allows for dedicated bandwidth allocated to an end-customer communicating over the Layer 2 Ethernet protocol. The BSoD capacity and features are embedded in the DOCSIS framework though there are restrictions associated with this. The BSoD limitations will be detailed in some of the subsequent sections dealing with VULA-like features and terminating segments of leased lines.

2 Wholesale products over CATV DOCSIS 3.0 platforms

From a generic point of view, WIK has identified potential wholesale products on CATV platforms operated according to DOCSIS 3.0 as listed here:

- **Wholesale local access (Market 3a)**
  - Duct sharing
  - Fibre unbundling and dark fibre
  - Amplifier access and frequency sharing
  - VULA
    - Local handover
    - Service-agnostic transmission (Layer 2 protocol)
    - Multicast support
    - Bandwidth control
    - Free Customer Premise Equipment (CPE) choice
    - Access link state control
    - Process control
- **Wholesale central access (Market 3b)**
- **High-quality aspects (Market 4)**
  - Terminating segments of leased lines
  - Quality-defined bitstream
- **Resale (no market number)**

The report will detail the considerations of the Market 3 wholesale products as structured above in the subsequent sections (2.1 and 2.2). The last two wholesale products listed above are not part of Market 3 of the EC recommendation, but they are nevertheless related to some of the Market 3 products. Consequently, they are listed for completeness and to briefly delineate them from the potential products considered in the Market 3 context (see products in the subsequent sections (2.3 and 2.4)).

According to WIK's observation,[5] the only wholesale Market 3 product currently offered by a CATV operator is wholesale central bitstream access for Market 3b. This can currently be provided by any operator. It is a regulated wholesale access product in Belgium (regional CATV operators: Telenet, Tecteo, BruTele, Numericable, AIESH) and

[5] See the market descriptions of the Belgian and Danish NRAs.

Denmark (TDC) (accounting for national conditions). All of the Market 3a products listed above are typically not available today, but at least in theory are technically possible.

While resale offers on CATV networks exist in some cases (section 2.4), for Market 4 wholesale products, there is only a theoretical technical option for implementation in DOCSIS networks (section 2.3).

The European Commission distinguishes[6] between physical and passive access products and non-passive access products, which one could also call active products because of the active electronic interface they require. In the case "where fibre physical unbundling is not technically or economically feasible or where the implementation of SLU unbundling would impede the realisation of the full benefits of VDSL2 vectoring … NRAs have been mandating virtual access products."[7] A virtual access product, also called VULA, is an active product that meets the characteristics mentioned under VULA in the list above, which enables a high degree of product differentiation for the wholesale-seekers, compared with the wholesale provider's own retail products. One can therefore distinguish between a physical/passive access product (i.e. duct, copper pair, fibre), an active product meeting the characteristics of a VULA and thus being an accepted active substitute of a passive product, and an active product not meeting these VULA criteria but for example meeting the criteria of a wholesale central access.

- **Wholesale local access (Market 3a)**
  - Duct sharing — physical/passive
  - Fibre unbundling and dark fibre — physical/passive
  - Amplifier access and frequency sharing — virtual/active
  - VULA — virtual/active
- **Wholesale central access (Market 3b)** — non-virtual/active

Thus, the Market 3 products can be classified in the physical and virtual products of Market 3a and the active (non-virtual) products of Market 3b (Market 4 and resale products can be classified as active products also).

2.1 Wholesale local access (Market 3a)

All wholesale products of Market 3a listed above can be provided in theory, assuming they comply with ideal circumstances and prerequisites; for example, in the case of duct sharing or dark fibre, the infrastructure has to exist in the relevant locations. In coaxial cable networks, however, such infrastructure is typically not available, as is described in

6 See Explanatory Note SWD(2014) 298 to the European Commission Recommendation of 9th October 2014, C(2014) 7174 final, section 4.2.2.1.

7 See footnote 6.

sections 2.1.1 and 2.1.2. Amplifier access/frequency sharing and VULA are technical concepts which in theory could be used for wholesale products, so they might be technically possible on a DOCSIS 3.0 network. However, these concepts also encounter implementation complexities or have insufficient capability, as will be described in sections 2.1.3 and 2.1.4.

2.1.1 Duct sharing

CATV networks consist of a core network connecting a master headend with hubs in the regions typically hosting the CMTS via fibre ring networks. There are also fibre cables from the hubs to the fibre nodes. From the fibre nodes to the end-customer premises, there are coaxial cables, either in a string or bus/tree topology, or as a star (see Figure 1-2).

It depends on a specific country if the fibre cables are deployed as direct buried cables, in ducts or as aerial cables on poles. In many countries, a mixture of deployment forms can be found. All forms may be constructed in a trench-sharing manner. Ducts and poles typically enable sharing, even if the original deployment and construction work has been completed. Sharing with others requires sufficient spare capacity besides the capacity required for the operator's own cables and the capacity required in addition to technical and operational reasons. Operational spare capacity is typically used to replace an existing cable for repair or upgrade reasons. This allows installation and connection of a new cable before the old one is removed, thus reducing the interruption of network operations.

The options for duct sharing also depend on the deployment forms for coaxial cables, which cover the last segments towards the end-customers' premises. They may be deployed in a direct buried manner, ducted, overhead on poles, or façade-mounted anchors etc. The options of sharing are the same as in the previous paragraph.

Whether the CATV network operator is obliged to offer its spare duct capacity to other telecommunication network operators depends on national legislation regarding the rights of way, and how the EC recommendation on cost reduction[8] is or will be implemented. By offering wholesale duct or pole capacity, the CATV network operator is also a wholesale provider able to host NGN and/or NGA network fibre cables, thus becoming part of an empty duct or free pole capacity market.

Wholesale-seekers are more interested in using wholesale infrastructure (ducts, pole capacity) when the offered infrastructure meets their demand with regard to the street segments covered. This could be called the degree of topology congruence. Also, the lower the price for the wholesale infrastructure offered, compared to the cost of

8 EC Directive 2014/61/EU of 15th May 2014 on measures to reduce the cost of deploying high-speed electronic communication networks.

constructing it on its own, the more attractive the offer is and the higher the probability that a wholesale-seeker might accept a deviation from its intended topology. If the hubs are collocated with the wholesale-seekers' core locations and if there is empty capacity at all end-customer premises, the situation would be ideal. It would also be a significant saving if the coaxial cable segments are ducted or aerially deployed and free capacity becomes available. However, if only a few segments are shareable (congruent topologies), one cannot even claim that there is a national wholesale duct and/or pole capacity market on the CATV network infrastructure at all.

2.1.2 Fibre unbundling and dark fibre

One can split the wholesale use of unlit fibre into fibre unbundling and dark fibre as wholesale products. Fibre unbundling allows the unbundling of Fibre To The Home (FTTH) between central fibre network node locations (i.e. at an optical distribution frame) and end-customer locations. In contrast, dark fibre is a more general wholesale business where the fibre segment is an intermediate fibre, not ending at an end-customer location.

In CATV networks, fibre cables today are typically deployed in national and regional rings connecting the hubs and from the hubs and CMTS locations to the fibre nodes. Because the final drop segments of the CATV network are coaxial, typically no fibre is installed today. As a result, a wholesale fibre unbundling business cannot currently be offered by a CATV network operator.

A dark fibre wholesale business might develop where there is sufficient spare fibre in the CATV network operator's fibre infrastructure, which is not required for future capacity enhancements (see RFoG below). So for today and the near future, the use of spare fibre for a CATV network operator by wholesale-seekers may only occur on a case-to-case basis where there is topological congruence (comparable to the ducts above) that leads to savings. As things currently stand, WIK cannot see a larger or even national offer for wholesale dark fibre by a CATV network operator.

The situation may change when RFoG[9] is rolled out, if at all. RFoG would require a Fibre To The Building (FTTB) or FTTH roll-out of the CATV network operator, terminating at small fibre nodes per building or even home. The fibres would then bypass the existing incumbent fixed telecommunication network operator who is concentrating on Fibre To The Cabinet (FTTC) instead. All economic investigations done by WIK or that WIK is aware of conclude that only very densely populated areas have a chance to deploy two sets of parallel broadband telecommunications infrastructure in a viable manner.[10] As a consequence, if such RFoG development becomes reality, the CATV network operator

9 See Figure 1-2 and Footnote 3

10 See Elixmann, D; Ilic, Dragan; Neumann, K.-H.; Plückebaum, T.:
The Economics of Next Generation Access; Report published by ECTA, Brussels, 16. September 2008.
Also see Analysys Mason:
The Business Case for Sub-Loop Unbundling in Dublin; Study prepared for Comreg, December 2007.

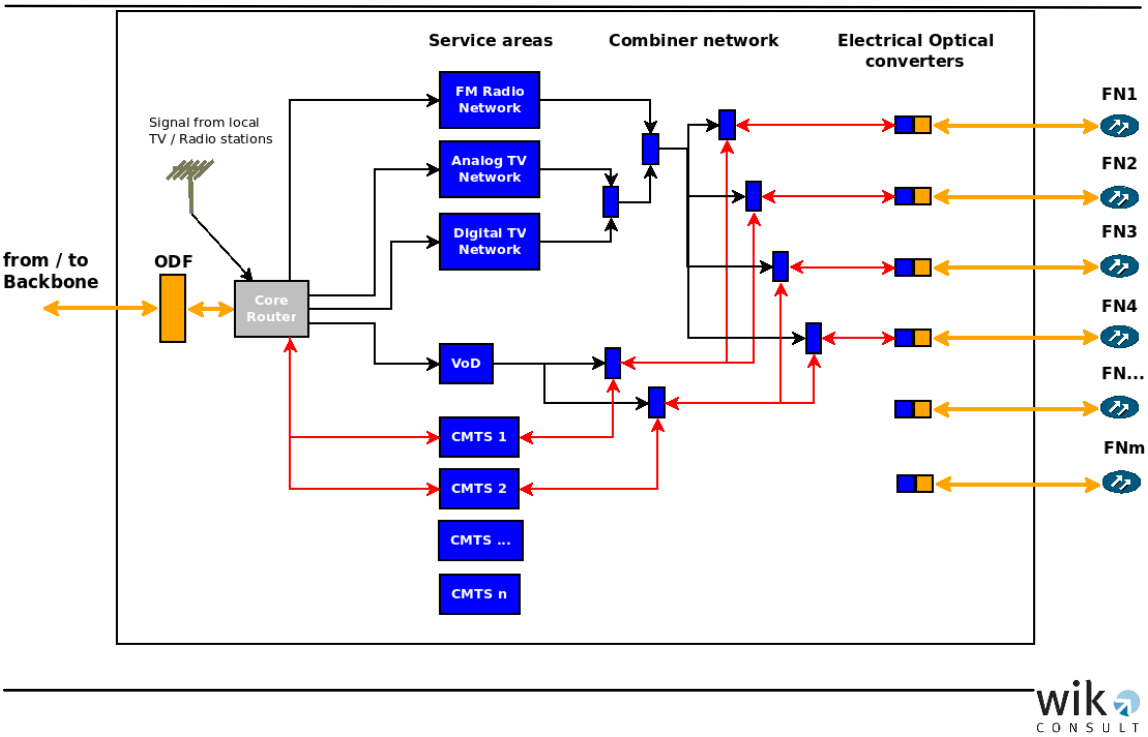
could become the new incumbent telecommunications operator. Such considerations are out of scope for the next five to ten years, because of the other capacity-enhancing options already described in Section 1.1, which require less investment.

2.1.3 Direct amplifier access and frequency sharing

In addition to duct sharing and fibre unbundling, frequency sharing (also called spectrum sharing) is a frequently mentioned option for access to cable networks by wholesale-seekers. One can understand spectrum sharing as allocating different channels (represented by different frequencies) within the total frequency spectrum to different providers. Although similar to choosing a different wavelength on a fibre line, the technical requirements are quite different on coaxial lines.

One significant difference lies in the fact that the wavelength division multiplex (WDM) hardware used at each end of a fibre line typically is provided by the same supplier and produces equal signals aligned to a frequency grid. In contrast, on coaxial lines, different hardware components from different suppliers produce different signals (e.g. TV, Video on Demand (VoD), DOCSIS) which could be arranged freely within the spectrum, but their use of the frequencies is not coordinated and thus may overlap. Figure 2-1 shows a typical setup inside a hub. Each blue box represents a group of hardware components of the same kind, as described in the boxes. Every hardware component group (box) reaching the same network segment behind a fibre node i (Fni) is set to a unique base frequency. The signals of the hardware groups (boxes) then get combined in a network of coupling elements (small blue rectangles). This frequency combination is conducted in a hierarchical manner in multiple tiers. The number of the tiers varies from site to site. In every tier each signal has to be attuned to the other signals of the same tier using amplifiers and attenuators pads. The whole combination process only consists of amplification and attenuation; no rearrangement of the signal frequencies is performed. Therefore, if a single component group is set to the wrong base frequency, the signals get mixed up and interfere and the transmission is distorted. This becomes even more difficult and error-prone if multiple providers have to attune their equipment regarding frequencies and signal strength.

Figure 2-1: Coupling of different frequency signals inside a hub



Source: ContaQ

In principle, frequency sharing on an RF (radio frequency) level between different providers is technically feasible. Nonetheless, this approach leads to operational problems (e.g. nearly static bandwidth allocations and high coordination effort between different providers due to ongoing cluster (fibre node) splits, fibre expansions and changes in transmission technology) which make it infeasible in practice. Similar problems arise for the amplifiers, as coupling the signals on the amplifier level does not differ from coupling them on the hub level and therefore leads to the same problems regarding signal frequencies and strengths.

Despite being technically possible, direct amplifier access and frequency sharing are error-prone and lead to huge coordination efforts; thus, the overall complexity decreases the chances of such an approach being implemented.

These problems are mostly solved if the access is managed in a non-direct manner, e.g. via Layer 3 network communication, where the sharing is done virtually inside the CMTS. The coordination efforts then are lifted to the software level where coordination is much easier. In this context, VULA comes quite close to direct amplifier access and frequency sharing. This will be discussed in section 2.1.4.

2.1.4 VULA and the characteristics required

The Wholesale Local Access Market (WLA Market 3a) as defined by the European Commission is usually provided via Local Loop Unbundling (LLU). Because of the construction characteristics of a coaxial cable (one central lead surrounded by a metal shield) serving a major group of customers (shared medium), physical unbundling is impossible on cable networks. In this case, the EC states that LLU should be replaced by a virtual wholesale access product (Virtual Unbundle Local Access = VULA) which could be considered a virtual counterpart of direct physical line access. The EC recommendation sets out three cumulative criteria for such a virtual wholesale access product to be included in Market 3a:

1. Access occurs locally,
2. Access is generic and provides access-seekers with a service-agnostic transmission capacity uncontended in practice, i.e. providing guaranteed bandwidths, and
3. Access-seekers need to have sufficient control over the transmission network.

2.1.4.1 Local handover

Local access, as understood by the European Commission, is one of the key characteristics for Market 3a products. It typically includes traffic handover at MDF or street cabinet level. The latter requires direct line access, which implies spectrum sharing on cable networks at an amplifier level as stated above. For this reason, local access on cable networks is economically/operationally feasible only at the MDF level, where the RF signals of radio and TV programs and data communication (from the CMTS) get assembled (combined) in order to be forwarded on the fibre to the fibre node. The CMTS in principle is the appropriate point to access a data communication connection to an end-customer within a CATV network. This is typically located on a local level.

The CMTS as defined in DOCSIS operates on an IP level. All of the cable operator's equipment is thus IP-based at the side connected to the core network. The IP protocol is typically used for bitstream services, so bitstream could also be offered at a local handover. As an exception outside the DOCSIS standard, Layer 2 access (as recommended by the EC for VULA environments) is also technically feasible, but only under the circumstances described in the next section.

2.1.4.2 Layer 2 protocol (service-agnostic transmission)

The second characteristic set out by the EC states that access has to be generic and has to provide a service-agnostic transmission capacity which is uncontended in practice. This is typically realised by Layer 2 access between the access-seekers and their

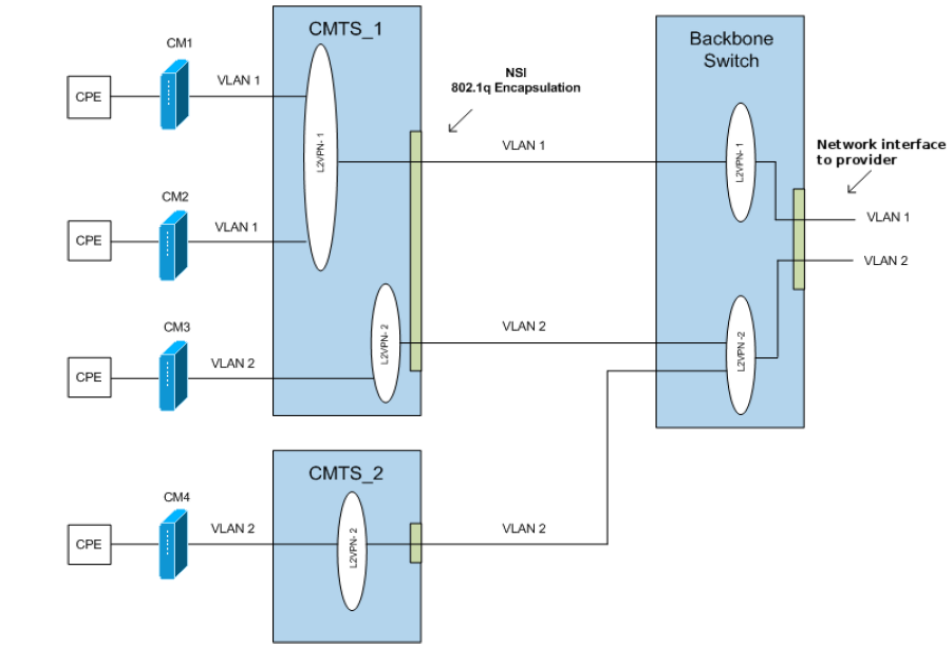
customers. The aspect of uncontended bandwidth mentioned in the second characteristic is dealt with in section 2.1.4.4.

However, as stated in the DOCSIS standard, a CMTS only has to provide an IP-based (Layer-3) service. The CMTS hardware may optionally provide Layer 2 services on a voluntary basis, if it supports the additional Business Services over DOCSIS (L2VPN/BSoD) standard. Thus, not all CMTSs support these features. Without analysing the DOCSIS equipment and the CMTS deployed by the Irish operators, one cannot say if these systems support BSoD at all, if they can be upgraded and at what cost.

According to this voluntary standard, each access-seeking provider gets its own Layer 2 Virtual Private Network (L2VPN)[11] within a DOCSIS-based network segment. Such a VPN is a network encapsulated in a more general network, which is protected against unauthorized access. All L2VPNs then represent VPN segments within the physical segment behind a fibre node on the coaxial cable segment. They only communicate in the DOCSIS data communication upstream and downstream channels and do not have access to the radio and TV frequency bands. Technically, this is either realised by an additional addressing feature called MPLS pseudowire switching (which is less well supported) or via 802.1q VLAN tagging, a well-known Layer 2 Ethernet protocol feature which is supported by a wide range of standard network equipment. The following figure shows the widely used VLAN tagging approach.

[11] L2VPN is a methodology where several user networks are transported in the same data stream but separated underneath each other by additional address information, identifying which VPN a data frame belongs to. In the Ethernet (Layer 2) protocol, “tags” are used in the standard protocol header. With multiprotocol label switching, labels are inserted between the Ethernet protocol frame and the IP header to uniquely identify each VPN. Both methods are standardised.

Figure 2-2: Different VLANs for L2VPN / BSoD



Source: BSA-Concept CATV network, NGA Forum Germany, WG Interoperability

In the example of Figure 2-2, a single provider wants to operate two different VLANs for its end-customers connected to two coaxial cable segments controlled by two CMTSs. The example therefore shows two different L2VPNs (L2VPN-1/VLAN1 and L2VPN-2/VLAN2) from the same provider spread over two CMTSs. Both CMTSs are connected to a backbone switch which provides interfaces to the different provider network gateways, thus also to the provider of the example (Figure 2-3 only shows the backbone switch interface of one provider, but several providers' interfaces can exist in parallel, all accessing separate VLAN structures such as those demonstrated here, in parallel (for simplicity, only one is drawn in the figure)). An upstream packet from cable modem CM3 arriving at CMTS 1 gets tagged with VLAN ID 2 and is then sent to the backbone switch. The backbone switch then decides based on the MAC address[12] if the packet should be forwarded to CMTS 2 (if this is allowed) or to the provider's gateway. In the downstream direction, the VLAN tagging is set by the provider before entering the backbone switch and gets removed at the CMTS level.

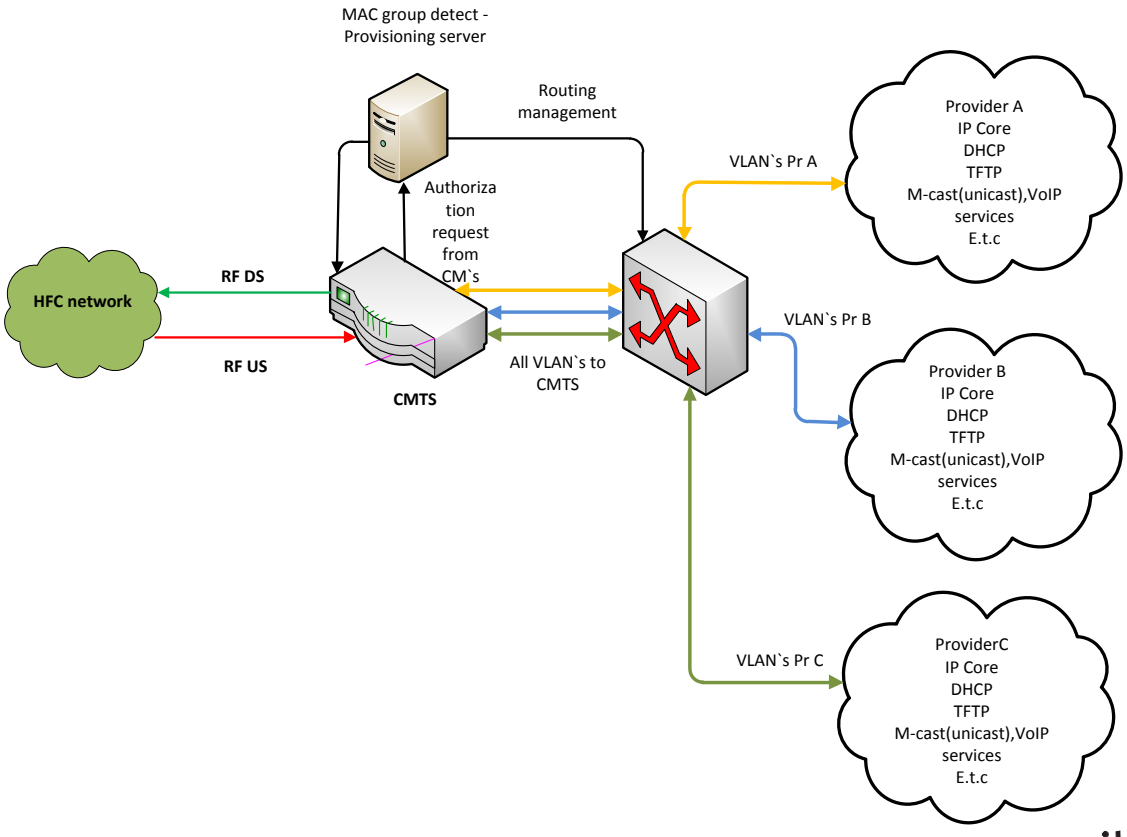
Furthermore, it is possible to connect company networks which internally use VLAN tagging within these L2VPN services. The already internally tagged packet reaching the CMTS gets tagged a second time. The technique is called double tagging, providing encapsulation of a customer packet (C-VLAN tag) within a service provider packet (S-

12 The Media Access Control (MAC) address is the Layer 2 address of the network nodes communicating in the Ethernet. It is globally unique.

VLAN tag). This double tagging allows for private customer (typically business customer) VLANs inside each of the provider's VLANs, thus supporting protocol transparency.

In normal (non-company) setups, all customer modems belonging to a single provider are assigned to a corresponding L2VPN, which consists of a logical group of one or more frequency channels within the RF spectrum called MAC Domain. One could imagine such a group as one big communication channel spread across all network segments. The wholesale network operator provides this provisioning procedure as a service for the access-seekers. A core switch/router behind the CMTS distributes the traffic coming from the different virtual network segments to the assigned provider gateways and vice versa. Figure 2-3 shows an example L2VPN setup.

Figure 2-3: L2VPN switching



Source: ContaQ

The example above demonstrates the main disadvantage of the BSoD/L2VPN solution. Each provider's MAC domain (consisting of one or more L2VPNs) is built on a unique set of frequency channels splitting the downstream and especially the more scarce upstream bandwidth into fixed slices. If one assumes an equal distribution of the channel capacity for three operators on the network, each provider gets 90 Mbit/s / 3 = 30 Mbit/s upstream

bandwidth in the example above, which is insufficient capacity to run three network operator businesses in a competitive environment.[13] Not only is the transmission volume restricted, but the peak bandwidth is too. Other capacity distributions can be realised, but they cannot overcome the restriction that the sum of all bandwidth is limited to 90 (max. 240) Mbit/s.

2.1.4.3 Multicast support

Streaming digital audio and video content is one of the major tasks for provider networks. A huge part of the downstream bandwidth and an increasing part of the upstream bandwidth gets consumed by all kinds of streamed media content.

That said, today's cable networks deliver a range of media streams (TV, radio, VoD, etc.) over different types of access technologies. Besides classic analogue TV, digital TV and VoD streams, which are delivered via DVB-C channels (Digital Video Broadcasting – Cable, outside the DOCSIS frequency spectrum), a rapidly increasing part of the media stream is IP-based and thus gets transported inside the DOCSIS spectrum.

While some of these streams are completely asynchronous from others (e.g. individually downloaded on demand like VoD or time-shift viewing), most of them still belong to the linear TV/radio category, so one stream serves all customers at the same time. The increasing demand for asynchronous streams causes capacity problems: if no further action is taken, a huge amount of individual copies streamed at the same time will consume a big share of the available bandwidth on their way downstream to the customer. To avoid this waste of bandwidth, cable networks support different types of multicast functionality.

Considering classic linear TV and radio services, a simple but effective multicast mechanism has been included in the CATV networks since the beginning: the standard channel bouquet. These channels could be provided by the access provider on a reselling basis.[14] Today, the standard channel bouquet is extended by IP Over The Top (OTT) services consuming bandwidth inside the DOCSIS (IP) spectrum. To address this increasing bandwidth consumption, some efficiency-improving multicast functionality was added to the DOCSIS standard. Internet Group Management Protocol (IGMP) v2 snooping was the first feature introduced in DOCSIS 1.1. This has been extended by the DOCSIS 3.0 Multicast DSID (Data Set Identification) forwarding feature which supports several IPv4 and IPv6 multicast protocols (IGMPv2, IGMPv3, MLDv1 (Multicast Listener Discovery), MLDv2). All these protocols allow optimisation and restriction of the multicast

13 Even with the theoretical maximum of eight channels of 30 Mbit/s each (see footnote 2), 80 Mbit/s per operator would remain, meaning the capacity and peak bandwidth are still constrained, making the system poor for capacity-guaranteed bandwidth for several customers at a time.

14 See also section 2.4. The access provider could also add some individual downstream radio/TV channels for operators' individual offers, besides the standard program bundle (bouquet). Including all TV channels in the IP downstream link at a fast speed would exceed its capacity (i.e. 150 SD channels with 3 Mbit/s each equals 450 Mbit/s, exceeding 400 Mbit/s downstream capacity).

downstream transmission capacity to only those channels being requested by the IPTV end-customers at a time. The other (not requested) channels are not transmitted, but will be included in the stream, when selected. Additionally, multicast Quality of Service (QoS) features have been added to ensure that video streams achieve the desired quality.

Thus, besides the option to resell the standard program bouquet, additional programs can be provided in the DOCSIS data channels, optimising the capacity consumption using dedicated protocols restricting the downstream to those requested channels. An efficient IPTV wholesale business is therefore a combination of standard program resale and special program wholesale bitstream.

According to the DOCSIS standard, these features are only available via the IPv4 and IPv6 forwarding engine. Packets routed through the L2VPN forwarding engine do not benefit from these features. To support multicast features on the Layer 2 level, access-seekers have to manage multicast traffic inside their virtual network for themselves or they have to separate their multicast traffic from their virtual network and deliver it via a downstream service flow shared between the wholesale provider and the access-seeker(s), i.e. as shown in the resale example in section 2.4.

Thus, there is no option for Layer 2 VULA multicast support within a CATV network infrastructure today or in the foreseeable future.

2.1.4.4 Bandwidth control

Having sufficient control over the bandwidth within the cable spectrum is one of the key criteria set out by the EC for VULA-type products to be included in Market 3a. It needs to be uncontended in practice and provide guaranteed bandwidth.

DOCSIS historically started as a best-effort service using a data request-grant methodology (fixed bandwidth capacity allocation per user in the upstream). This concept changed with the introduction of service flows in DOCSIS 1.1, giving access to upstream capacity for the end-customers:

- Unsolicited Grant Service (UGS)
  A fixed number of timeslots is periodically reserved for a single modem
- Real-Time Polling Service (rtPS)
  Similar to UGS, but the modem must ask for the reservation, otherwise the timeslot is free to use for other modems
- Unsolicited Grant Service with Activity Detection (UGS-AD)
  A combination of UGS and rtPS, switching from UGS to rtPS and back due to missing activity/reactivation
- Non-Real-Time Polling Service (nrtPS)
  Guarantees a transmission even if the network is congested

- Best-Effort Service (BE)
  Modem and CMTS simply do their best to send the data when possible

Most of the methods (access protocols) were designed with VoIP as the use case in mind, providing a fixed number of timeslots for sending data upstream and thus guaranteeing a constant bit rate and capacity (relevant for voice transmission at a dedicated quality).

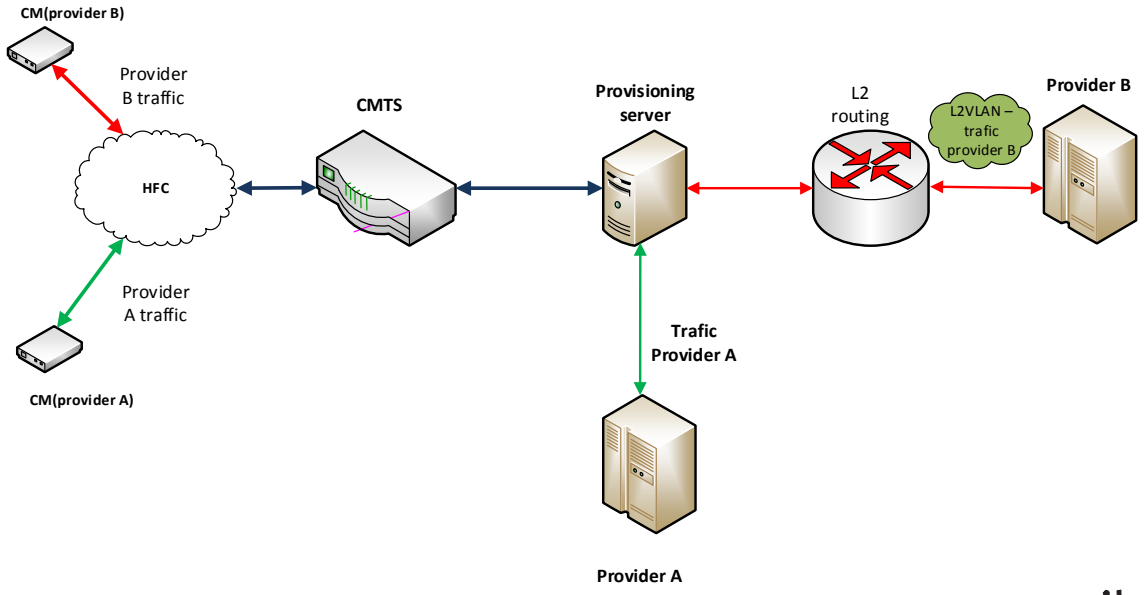
With the concept of service flows, one is able to get a guaranteed bandwidth for different types of traffic. However, this does not necessarily include a multi-tenant separation of provider networks. To achieve service-agnostic transmission capacity, the “collision domains” of the different providers have to be separated from each other. This could be achieved using the concept of MAC Domains[15] for the upstream and downstream direction, which is supported in DOCSIS 3.0 (the current DOCSIS standard) as well as in DOCSIS 3.1 (in the future). Each provider (wholesale provider and access-seeker) gets its own MAC Domain for each fibre node. All upstream and downstream channels exclusively assigned to such a MAC Domain then provide a guaranteed per provider bandwidth within the network segment.

For the access-seeking providers, the backbone switch and the provisioning system of the wholesale provider represent the “interface” to their customers behind the CMTS. The switch hosts the PoI (Point of Interconnection) ports where the traffic is transferred between the networks, and the provisioning system hosts the interface to the intercarrier process gateway (see section 3). Although these interfaces could be seen as a service-agnostic wholesale access solution, it is restricted to IP-based traffic (Layer 2 services are not guaranteed by the DOCSIS standard).

A virtual wholesale access product providing a generic solution, as demanded by the EC, is typically understood as Layer 2 access for the access-seekers. Thus, the concept of MAC domain service groups is clearly outperformed by the L2VPN/BSoD solution regarding the completeness of the feature set. The following figure shows an example setup.

15 A DOCSIS MAC Domain is a logical unit managing a set of upstream and downstream channels. A CM is registered to only a single MAC Domain. Technically these MAC Domains are represented by MAC Domain CM service groups for the different fibre nodes. See DOCSIS 3.0 section 5.2.7, CM-SP-MULPIv3.0-I29-151210 for further details.

Figure 2-4: Multiprovider solution



Source: ContaQ

In this setup, the wholesale provider (Provider A) is able to directly connect its hardware whereas the access-seeking provider (Provider B) is connected via an intermediate L2 switch.

The bottleneck in the upstream channel will soon be totally consumed by both of these methods if uncontended upstream capacity is provided. A demand of nine symmetrical connections of 10 Mbit/s uncontended already exceeds the upstream capacity available.

2.1.4.5 Free CPE choice

Although cable networks are built on a bundle of different technologies, each of them is well documented and standardised. TV, radio and VoD channels are built on the DVB-C (or DVB-T) standard and internet-based services as well as VoIP services are based on DOCSIS. In such an environment, all providers (the wholesale provider as well as the access-seekers) are able to use the standard equipment they want to offer on the customer side (tested cable modems and CPE), and to take effective control over the network in a way that allows product differentiation. Thus, the CPE may be freely chosen among all systems offered and meets the appropriate DOCSIS standard, and the cable modem typically is the operator's network endpoint and determined by them.

2.1.4.6 Access link state control

To be able to manage their own virtual network in case of an incident, an access-seeker needs to get sufficient control of the link state of his customer's cable modem. By this, the access-seeker may control the modulation on the access line (connection, link) used by the modem, change it or other access link parameters, and read transmission failure messages and statistics etc. According to the DOCSIS 3.0 standard, each CMTS must implement the CMTS CM Registration Status Service Definition (CMTS-CM-REG-STATUS-TYPE) which could be read out via several protocols (see next section) along with other information useful for debugging and incident analysis. The wholesale provider could offer this information via a service interface to the access-seeker. From a technical point of view, a wholesale-seeker could control its access lines within the wholesale provider's network. However, access to the cable modems by several operators would require an additional multi-tenant facility,[16] mutually protecting the other operators' access lines from unauthorised access, a feature not available yet as an integrated on-the-shelf characteristic of the currently installed OSS/BSS of CATV network operators.

2.1.4.7 Process control (related to service management)

Each access-seeker must also be capable of controlling its (virtual) part of the equipment (the systems providing and operating the end-customer connections) without gaining direct access to the equipment and the wholesale provider's customers. These features build a superset of the previously mentioned multi-tenant access link state control principle and are discussed in chapter 3 from the operational point of view.

Technically such a feature set includes configuration and fault management as well as performance and account management. Each access-seeking provider therefore must be able to set configuration parameters and receive fault messages for the CMTS and the cable modems as long as the information is associated with their customers. An interface system offered by the wholesale provider filters the incoming requests from the access-seekers and translates authorised requests into machine-specific requests and vice versa.

In case of DOCSIS hardware (CMTS and CM), these requests and fault messages are part of the DOCSIS specification.[17] The interface system itself communicates with the CMTS directly via SNMP (v1, v2c) or IPDR, (Internet Protocol Detail Record) which are both mandatory. So the basic features for remote control exist, but it remains unclear how to restrict the access of each provider to its own end-customers only and how to guarantee that the other providers' customers may not be harmed, intentionally or

16 A multi-tenant facility allows the virtual separation of software processes operating in the same environment and on the same set of resources in a manner such that each of the processes does not affect the resources of the other processes. Multi-tenancy is a prerequisite for multi-operator access to a wholesale provider's OSS.

17 See Operations Support System Interface Specification (CM-SP-OSSIv3.0-I27-150827).

unintentionally. The requests and fault messages could only be performed by multi-tenant add-ons for the network operating system, which are not available as a standard feature, if at all.

2.1.5 Market 3a wholesale network infrastructure availability (summary)

The physical wholesale products which might be offered over CATV network infrastructure (sections 2.1.1 and 2.1.2) typically cannot be provided in a wholesale manner because of the lack of spare infrastructure. Typically, empty or unused spare ducts, poles and fibres in a topological congruence (in areas with demand for it) do not exist.

The direct amplifier or frequency access can be supported by the network infrastructure equipment, but has a high degree of complexity and manual operational work and coordination and is error-prone, so should be excluded from a general wholesale approach. In addition, it also reduces bandwidth for the wholesale operator, thus remains an option only if there is a lack of traffic load in the network.

The options for wholesale VULA offers are constrained by insufficient Layer 2 protocol support (service-agnostic transmission), which is not mandatory in the DOCSIS standard for now and the future. Regarding the support of multicast services, the DOCSIS standard is based on IP and thus supports IP-multicast protocols only. Using these IP-multicast protocols in a shared IP downstream communication channel consumes a high bandwidth share of the total capacity and thus is inappropriate for a complete channel bouquet, thus should be restricted to some special offers (see section 2.1.4.3). The more efficient solution would be a resale of the transmitted TV channels. The multicast bandwidth control features of DOCSIS are based on the IP, but are not available in releases 3.0 and 3.1 for the Layer 2 protocol.

Free support of CPE may be supported by DOCSIS, but also depends on the operators and their coaxial frequency alignment. Also, link state and further process control functions exist within DOCSIS 3.0 and above, but the use of these features by wholesale-seekers requires multi-tenant capabilities of the network operating systems. Such multi-tenancy is – according to WIK's knowledge – not a standard feature of any network operating system, but has to be developed on demand.

The capacity of DOCSIS 3.0 in the upstream direction is greatly restricted. Offering wholesale bandwidth would reduce the capacity for the remaining wholesale providers' own customers significantly and would prevent future developments in achieving symmetry in upstream and downstream traffic. Furthermore, uncontended and symmetrical bandwidth could only be provided to a very limited extent and to the detriment of the remaining users.

The bandwidth improvements of DOCSIS 3.1 cover upstream and downstream at the same scale, so do not improve the traffic asymmetry characteristic. If the upgrades are performed on the existing customer capacity demand evolution, the upgrade to DOCSIS 3.1 will not improve the operator's openness to enter a wholesale business.

In summary, WIK does not envisage a general network infrastructure system that supports VULA as a mandatory or voluntary offer in DOCSIS 3.0 or 3.1 systems within the next three to five years.

2.2 Wholesale central access, bitstream (Market 3b)

In contrast to the wholesale local access (Market 3a), the wholesale central access market provides central traffic handover at core sites next to the backbone connection of the wholesale provider. The traffic is then routed through the wholesale providers' network down to the end-customers on a best-effort basis with no guarantees for bandwidth, latency, etc.

Such access only provides the transport of IP-based services with no or at most limited control over the transport network by the access-seeker and thus only allows bitstream-based products with reduced capabilities for access-seekers to differentiate their offers.

Regarding cable networks, the traffic handover can take place starting at the CMTS locations (MDF site level) and at any IP node level upwards in the network. According to the DOCSIS standard, all CMTSs are Layer 3/IP-based network units and therefore the support for bitstream-based products is assured.

Such network infrastructure equipment has already been available for a longer while,[18] with any DOCSIS 2.0 equipment and the subsequent releases supporting such features. WIK assumes that the reason why only a few CATV network operators offer such wholesale services is that the other operators have sold a large share of the upstream network capacity to its retail customers already and have no need to offer wholesale products, enabling competitors to enter the retail market by limiting its own scarce upstream growth capacity.

18 DOCSIS 2.0: CM-SP-RFIv2.0-C02-090422, Section 5 (p. 29), http://www.cablelabs.com/wp-content/uploads/specdocs/CM-SP-RFIv2.0-C02-090422.pdf. This document was actively worked on between December 2001 and April 2009.

2.3 High-quality access (Market 4)

2.3.1 Terminating segments of leased lines

The high-quality access market was designed with business users in mind. There is a wide range of high-quality connections in the market starting with low bandwidth connections at the entry level (64 Kbits/s) and ending with connections up to 100 Gbit/s for large business customers, with a current trend towards 10–100 Mbit/s Ethernet lines. The bandwidth is typically symmetrical and is dedicated exclusively to the one business user.

Regarding cable networks, such demand (10–100 Mbit/s) can be served in the downstream direction without problems. Furthermore, if L2VPN/BSoD is supported by the CMTS, a generic and service-agnostic bandwidth that is uncontended in practice can be provided for business customers downstream. However, the situation appears different for the upstream direction where a DOCSIS 3.0 CMTS supports up to 90 Mbit/s in total per network segment. Although it is possible to reserve a fixed bandwidth for a single customer, those connections consume a permanent bandwidth taken out of the scarce upstream bandwidth (because of the Time Division Multiplexing (TDM) used in the upstream) that would otherwise be accessible to all other customers connected to the same fibre node segment (due to the sharing characteristic of CATV networks).

Given a 2 Mbit/s symmetric connection (which is quite outdated for today's average leased line), such an option could only be supported for a few lines on a single network segment due to the large number of customers (between 500 and 2500) connected to a single fibre node segment. Additionally, a current CMTS implementing the BSoD standard only supports point-to-point connections towards the cable modems and thus external hardware is needed for switching, leading to higher implementation complexity.

For these reasons, most of the cable network operators tend to connect business customers directly via fibre lines, if this is economically feasible in the end-customer's area. WIK sees no option to offer terminating segments of leased lines over CATV networks in a general wholesale offer and to a wider extent. On a larger scale, from WIK's point of view, this is also the case for DOCSIS 3.1 networks, at least for leased line capacities of 100 Mbit/s and above.

2.3.2 Quality-defined bitstream

Dedicated IP networks like YouTube and Netflix trigger a second upcoming market segment with demand for high-quality access. These networks consume extra bandwidth within the provider's total bandwidth. Although it might be possible to easily share this bandwidth between the wholesale provider and the access-seekers, this could be an area

for differentiation between the operators. In particular, access-seekers might use this area for new higher-quality products, for which they might also pay more.

Some IP-based services have a strong asymmetric traffic profile which are ideally transported over CATV networks because of their large downstream capacity. On the other hand, in today's cable networks, some network segments have more than 1500 customers behind a single fibre node. If several wholesale providers offer such high bandwidth products over the same network segment, one might run out of downstream capacity. Furthermore, if one or more of those access-seeker’s IP networks demand upstream capacity (e.g. twitch.tv), one runs out of capacity even faster (as stated above). Due to the shared characteristic of the CATV networks, wholesale offers for a quality-defined bitstream are limited due to capacity bottlenecks in any case. This also holds, on a wider scale, when upgrading to DOCSIS 3.1.

2.4 Resale on CATV networks

CATV operators in Belgium resell CATV channels or even offer individual downstreaming of some TV channels for wholesale buyers in the TV frequency band instead of enabling IPTV multicast in their IP bitstream offers due to bandwidth constraints. This demonstrates that CATV channel resale can be relevant. Section 2.1.4.3 gives additional examples of a combination of resale and wholesale bitstream in order to manage the bandwidth scarcity for multicast offers in DOCSIS 3.0 CATV network environments.

Resale is no longer considered within the predefined markets for ex-ante regulation. Therefore, resale can be excluded from the considerations here; however, it is worth being aware that it may come into force as an additional supporting obligation for a regulated bitstream product in order to at least manage IPTV applications in a capacity-efficient manner.

3 OSS interaction between wholesale providers and access-seekers

There are many interaction processes between wholesale access providers and wholesale access-seekers. Most of them cover the ordering of services, operating them and repairing faults. Some deal with billing, changes or planned upgrades in the access network that may affect end-customers, as well as the provider's own retail and wholesale markets. These processes cover the whole service life cycle. An overview of such processes is given in Table 3-1.

Table 3-1: Generic wholesale interaction functions related to processes

OSS function	Remarks, characteristics	Available in Ireland
Ordering		
Prequalification	for first time connection, upgrade, move	x
Order an access connection	Incl. confirmation, appointment and on-site work, order monitoring, delivery day communication, order delay	x
Operating		
Change access connection parameter	bandwidth, QoS, transmission quality	x
Move to a new location		x
Terminate an access connection		x
Change between retail operators		
Proactive line monitoring and testing	by the wholesale-seeker/retail operator	x
Fault repair		
Fault notice		x
Fault monitoring		
Fault interaction	incl. appointment and on-site work	x
Fault delay		x
Fault release (end notice)		x
Proactive fault notice	major faults in wholesale operator's network	
Other processes		
Escalation procedures	for order and fault, flat compensation determination and payment	x
Billing interaction	if required (e.g. volume-dependent pricing, QoS-dependent pricing), typically as a result of parameter changes	
Network change notification	for planned changes, upgrades and maintenance work	x

Ideally the processes for both sides – wholesale access provider and wholesale access buyer – interact in an automated manner, exchanging the actions and information required via an electronic process gateway. Automatically operated processes have two major advantages: they typically can be performed much faster and with significantly fewer faults, resulting in higher end-customer satisfaction. The existing wholesale market in Ireland is used to working that way with its incumbent fixed network operator Eir.[19]

If there is more than one wholesale operator, the processes of interaction between wholesale providers and their customers should be standardised in order to prevent barriers to entry. An easy-to-implement approach is to use the data exchange formats and protocols and the mode of process interaction which have already been established. It would be more complex, time-consuming and expensive to define, implement and establish an abstract and neutral mode of interaction.

If a CATV network operator intends to offer (or is obliged to offer) wholesale access services in Ireland, the Irish wholesale customers would be keen to not have to change their existing wholesale operation processes (with Eir), or at least only if this is due to product changes, ideally offering advantages over the previous product offering. For a CATV network operator offering wholesale services, this would mean not relying on those automatic wholesale process operations the market is already used to. It would be difficult to imagine re-establishing manual processes or information exchange, e.g. by fax, with a new wholesale provider unless there is a trade-off (e.g. low prices or different products).

Therefore, the wholesale CATV operator is forced to

1. establish a process gateway,
2. which operates as identically as possible as the existing processes, even if the critical mass of orders and customer connections is not yet reached, in order to establish and operate such a gateway in a profitable manner.

It is not (yet) common for CATV operators to offer wholesale services. Therefore, their suppliers do not offer systems providing multi-tenant functionalities and interfaces for wholesale customers in their automated service provisioning (order) and operation processes. This also holds for the CATV network management systems in their fault analysis support. Establishing such (wholesale/multi-tenant) features in the existing systems therefore requires a major system development effort, despite the fact that single process elements are available (see sections 2.1.4.6 and 2.1.4.7).

An exception may exist in the trouble ticket systems of both sides, because these systems typically are not technology-dependent and are also used by traditional fixed and mobile network operators and usually allow for the electronic exchange of the trouble tickets.

19 Table 3-1 marks those generic processes which are covered in Eir's automatic process interface according to WIK's understanding. These automatic processes are those the Irish wholesale market is already used to and may be expected in new wholesale offers also.

The exchange of trouble tickets can be the means of communication during fault repair; this may not be a complete service but it certainly offers a high level of interaction.

In general, processes of ordering and operating cannot be coordinated electronically without a major effort by the CATV network operator. If the operator is not using the existing processes for the unique platform or if the CATV wholesale provider offers new and different products with different electronic processes, the wholesale customers also have to expand their process machines.

To add to these more general but important remarks, the report will continue this section by describing the processes listed in Table 3-1 in more detail by giving short overviews and focussing on the relevance for the CATV network operators. While the intended products for this consideration are active wholesale products, this could be transferred to wholesale passive products and the amplifier access/frequency sharing product in an analogue manner, if they ever become relevant at all.

The EC explanatory note demands that virtual wholesale products in Market 3a offer "sufficient control over the transmission network to consider such product to be a functional substitute to LLU and allow for product differentiation and innovation similar to LLU. … The access-seekers' control of the core network elements, network functionalities operational and business process as well as ancillary services and systems … should allow for a sufficient control over the end-user product specification and the quality of service provided."[20] This high level of process interaction is not demanded for bitstream services (Market 3b). A lack of such product control functions may even contribute to classifying a wholesale product belonging to Market 3b instead of 3a.[21] Nonetheless, such process control features may ease market entrance for new wholesale offers.

Today and for the foreseeable future, there is no technical opportunity to offer VULA wholesale products on DOCSIS 3.0 (and 3.1) CATV networks.[22] Consequently, there is no need to analyse close process control and interaction between wholesale provider and wholesale-seeker OSS platforms for VULA. Nonetheless, the study will analyse this process interaction in a generic manner for future use and also for applying process interactions to Market 3b entrance options.

20 SWD(2014) 298, section 4.2.2.1.

21 SWD(2014) 298, section 4.2.2.2.

22 BSoD may offer such a service to a limited amount of customers, if sufficient capacity is available.

3.1 Ordering

3.1.1 Prequalification

Prequalification allows a wholesale-seeker to determine, in advance of closing a contract with an end-customer, if the product's service is available from the wholesale provider at the location of interest, and how much time it may need to provide it. This request may also result in an access capacity reservation for a short time, namely the time required to typically process an order. Prequalification may be required not only in case of buying a connection for the first time, but also during the contract lifetime if upgrades are requested or if the customer intends to move from one location to another.

Prequalification is an important process element preventing discrimination of the wholesale-seeker because typically the network operator itself knows where they are able to serve end-customers. CATV network operators know about their coverage areas, and also of near-net buildings[23] that might be or could be connected to their network within the near future and with limited effort. They also know about the capacity situation within their related coaxial cable segment by monitoring their fibre nodes. So, while the prerequisites are given, the general obstacles described in this chapter's introduction (no process gateway, no multi-tenant function, i.e. allowing internal performance data to be hidden) hold.

VULA and bitstream are services no CATV network operator would provide in an EoI (Equivalence of Input) manner. Highly automated and reliable service provisioning and monitoring functions (OSS) already exist on all CATV network platforms. These OSS platforms do not currently have multi-tenant features – as far as WIK is aware. Consequently, one could not expect EoI processes (internal and external (wholesale) demand are processed equally) to be provided. Thus, such multi-tenant features would have to be developed to only offer wholesale services.[24]

3.1.2 Order an access connection

The business processes to order an "access connection", order "change service characteristics" and order "move to a new location" all have to be processed within a CATV network operator's network and thus could in principle be used by wholesale-

[23] Near-network buildings can be connected to an existing network with limited effort, because they are close to the existing infrastructure. A subset of the near-net buildings are buildings also called "homes passed". Here the network is already designed to connect them.

[24] Besides many other arguments against offering wholesale Market 3a products, there is also a trade-off between the cost of upgrading the OSS systems towards multi-tenancy and the additional wholesale income the operator could gain.

seekers also. This requires multi-tenant functionality within the CATV network operator's provisioning systems and an appropriate process gateway would need to be developed.

The interaction between the sales staff and field service and the respective services of the wholesale-seeker typically differ. The interaction with a wholesale provider's own field service is directly controlled by the workforce management system. In contrast, the interaction with the wholesale-seeker's field service is operated via the process gateway and typically is controlled by the wholesale buying group of the wholesale-seeker before entering its workforce management system. These interactive functions thus have to be developed in addition to the existing functions.

There are several process elements and gateway communication cases to be considered. These include

- communicating the order confirmation,
- agreeing on an appointment for on-site work, if required,
- allowing the order steps to be monitored by the wholesale-seeker,
- communicating the delivery day, and
- postponing delivery in case of order delay.

A typical complexity of the appointment process is an appointment failure, either because the field service did not get access to the location because the customer was not there, or the field service did not attend the appointment. If this happens, the appointment has to be rescheduled. In the case of a missed appointment, a typical debate might arise: who has to bear the cost of the missed appointment and the second attempt on the one side and the extended period without service on the other side, if the field service claims the customer was not there but the customer claims to have been at the right location at the right time.

3.2 Operating

3.2.1 Change access connection parameter

The relevant parts of changing access connection parameters including those related to the intercarrier billing, are described above within the order processes (section 3.1). This section covers the changes to be processed within the network operation.

The changes a wholesale-seeker might want on behalf of its end-customers are typically comparable with the changes of the wholesale provider's own retail customers. They can be defined as changes within the wholesale product specifications. One can assume that the changes are initiated by the order process and will be processed within the network operating systems of the wholesale provider like any other product modification. In the

wholesale scenario, the change-ready notification has to be communicated through the order process and its process gateway to the wholesale-seeker.

While this will hold for changes in qualitative parameters like access bandwidth, transmission quality or QoS (if available at all, typically not part of Market 3b), the change of a CPE (i.e. with new and better characteristics) may be processed in a different manner, when the CPE is provided by the wholesale-seeker. Thus, process modifications are required if introducing wholesale business for a CATV network operator.

3.2.2 Move to a new location

If a customer is moving to a new location, the field service and network operational staff of the CATV network operator may communicate directly with its own retail customers. Wholesale customers communicate through the wholesale-seeker's organisation. This will require add-ons in the operational process for approaching the wholesale customers in a different manner and will require supporting features in the interoperator process gateway.

3.2.3 Terminate an access connection

The termination of a service has to be performed for the wholesale provider's own retail products. It is more or less the same in the wholesale case, provided that the multi-tenant function and the process gateway function exist. A major difference between wholesale and retail is related to the contractual relationship: for wholesale, the wholesale contract and the wholesale billing have to be reduced in line with the terminated service; for retail, the retail contract and the retail billing have to be terminated. If wholesale-seekers operate over the multi-tenant function in the wholesale operator's OSS it cannot allow any service to be terminated which does not belong to the related wholesale-seeker.

3.2.4 Change between retail operators

A special challenge is the process of changing the retail operator but keeping the wholesale provider and the existing end-customer's wholesale access connection if two external wholesale customers are involved but the end-customer remains the same. From the wholesale provider's point of view, the existing access connection may remain active but the service handover interface has to be changed. Also, all administrative communication relations (i.e. the contact points for sales and operations) have to be changed, including the wholesale contracts (one terminated, one new) and the wholesale billing. It becomes even more complex if failures occur in one of the interoperator process elements, such as if the provider change cannot be completed. Here, a typical solution is a safe harbour concept, which means that the service will be provided by the original

provider until the problems are resolved and the customer switch-over can be performed reliably.

Such cases can only occur if several wholesale relations exist. They are completely new for an operator running its network only for its retail customers, now entering the wholesale business. Such provisioning processes simply do not exist in such an environment and have to be developed from scratch.

3.2.5 Proactive line monitoring and testing

It is in both parties' interest – the wholesale access-seeker and the wholesale access provider – that the access-seeker has access line state monitoring and testing for all their retail customers connected via this wholesale provider. For the access-seeker, it enables fast responses during a call in which the end-customer is complaining about faults or poor connections. Furthermore, the access-seeker can claim in a qualified manner to its wholesale provider. For the wholesale access provider, it reduces the amount of unjustified end-customer claims, which in turn reduces the required effort and interaction, and also enables faster and more qualified resolution of the problems.

One can assume that the wholesale provider has such monitoring functions in its network operating systems and these now have to be made accessible in a multi-tenant manner for the wholesale-seekers, typically over a dedicated gateway function in real time (see also section 2.1.4.6 und 2.1.4.7).

Of course, wholesale-seekers buying access services from different sources (e.g. from different wholesale access providers) have a strong interest in these dedicated interfaces operating in the same manner in order to make their business easier to handle, reduce cost and failures and thus increase customer satisfaction.

3.3 Fault repair

Fault repair is a critical process in the relationship between a wholesale provider and its wholesale customers, because it directly affects the customer satisfaction of the wholesale-seeker's end-customers. From a regulatory point of view, all processes should be performed in a non-discriminatory manner. All fault interaction between the wholesale-seeker and the wholesale provider requires communication through the intercarrier process gateway; thus, the wholesale provider's processes have to be adapted accordingly for the wholesale provider's business.

3.3.1 Fault notice

Typically, the wholesale-seeker's end-customer reports a fault to its service provider, the wholesale-seeker. The wholesale-seeker will monitor the line state and try to analyse the situation with the tools available to them (see Section 3.2.5). If the wholesale-seeker finds the problem to be the wholesale provider's responsibility, they will forward a qualified fault notice. This has to be performed using agreed communication means and processes. The wholesale provider may have a dedicated entry point into their network operation staff for these kinds of qualified fault notices.

3.3.2 Fault monitoring

There are two general aspects for fault monitoring:

1. The wholesale provider monitors its network and discovers faults.
2. The wholesale-seeker is able to monitor faults in the network of the wholesale provider.

In case 1, the wholesale provider shall communicate access line faults to the wholesale-seeker in advance and independently from a fault notice from the wholesale-seeker's end-customer over the intercarrier process gateway. This may require process changes on the wholesale provider's side if such messages are not directed to its own retail customers as well.

Case 2 is more problematic because the wholesale provider has to protect its network against any harm from outside and also has to exclude monitoring functions of the access lines of its own retail and other operators' wholesale customers, which requires a well-designed, multi-tenant monitoring system. Such systems typically are not available for CATV networks. Instead, there may be a fault state trouble ticket exchange on a regular basis in order to enable the wholesale-seeker to answer questions from their end-customers or to proactively inform them. This should include an estimation of the fault repair duration. According to WIK's experience and observations, such information exchange is not common in normal retail customer relations and is only used for higher-level business customers. Thus, process changes required of the wholesale provider depend on what process was used before entering the wholesale business.

In both cases, the intercarrier process gateway has to support the communication.

3.3.3 Fault interaction

The interaction for repairing faults in more complex cases in a wholesale relationship involves three parties instead of two. The two involved in a non-wholesale scenario are the network provider and the end-customer. For a wholesale scenario, part of the network

production is performed by the wholesale-seeker, and the end-customer relation is then moved to the wholesale-seeker. This means the process has to be amended accordingly. While fault monitoring communication and the exchange of measurement protocols may be performed using a trouble ticket exchange, in-depth fault analysis requires interaction between the field service and at worst the operation staff of both networks. This typically is performed over the phone or even by Skype meetings, requiring personal interaction instead of automated information exchange. However, some elements like arranging end-customer visits should use existing process elements, of course.

3.3.4 Fault delay

Repairing a fault might require more time than originally estimated. If the wholesale provider realises that they cannot complete the work within the estimated repair schedule, the wholesale-seeker shall be informed by a message, either within the trouble ticket exchange or as a separate message, both routed over the intercarrier process gateway.

Regarding the process changes required, please see Section 3.3.2, case 2.

3.3.5 Fault release (end notice)

When a fault has been repaired, the end-customer will usually be informed by phone call or another message. For a wholesale business, either the wholesale-seeker will be informed, and will then inform its end-customer, or the wholesale provider will inform both simultaneously. The latter solution is not very common because the wholesale-seeker's end-customer might be addressed by two operators, depending on which side the fault has been located. In the case of a fault in the PoI or interconnection link, there would have to be an agreement about who informs the customer.

In any case, the fault release notification process requires enhancements for a wholesale business.

3.3.6 Proactive fault notice

Major faults may occur in a network affecting a large number of end-customers, both in retail and wholesale. Such failure could be in fibre nodes, backhaul fibres, hubs, etc. In order to be able to react to bursts of failure calls in the call centres, the wholesale provider should inform its wholesale customers immediately when such failures occur, describing the area affected. This enables the wholesale customers to react accordingly, e.g. switching announcements, putting information on its homepages. Such failure reporting shall be continued using a regular monitoring report of the wholesale provider, providing details of the possible fault cause and estimated duration, with regular updates if required.

One can assume that such processes are already implemented in a CATV network provider's operating process and therefore only some addressees will have to be added. One could filter the information directed towards the wholesale-seeker so that only those affected by the fault will be notified, and in addition delete internal information which shall not be exchanged with the wholesale customers. These features would require the process to be adapted according to these wholesale requirements.

Such information will be exchanged over the intercarrier process gateway.

3.4 Other processes

3.4.1 Escalation procedures

It is possible that order or change processes may not be finished on time or agreed repair times may be exceeded. For business customers (not residential ones), it is not uncommon to escalate such problems in order to allocate new or additional resources to enable a faster resolution. This process escalation should also be applied in a wholesale relationship. Escalation will typically be performed in a stepwise escalation procedure: the longer the agreed upon time is exceeded, the more involved the senior management up to the board will be. This communication may be handled over the intercarrier process gateway for the first levels of escalation, but at higher senior level will be performed by individual peer-to-peer communication.

Process changes are required for those operators that have not installed such escalation processes yet, i.e. for internal use. Typically, such processes, if existing, have to be adapted to suit cases, time frames and addressees. It is important to update escalation partner contact details at every change.

3.4.2 Billing interaction

In a wholesale relationship, intercarrier billing information has to be exchanged. At a minimum, the wholesale provider sends its intercarrier invoice to the wholesale-seeker. This can be performed using the intercarrier process gateway, but any other electronic buying platform interface allowing for standardised electronic billing can also be used. One special condition has to be met: intercarrier invoices may include large volumes of billing data sets. This will depend on the wholesale tariff structure (flat fee vs service-oriented billing).

In any case, intercarrier billing is not comparable with retail customer invoicing and is typically performed by a dedicated and separate billing software suite. When deciding the requirements for a wholesale business, this additional cost should be taken into account.

This process may be outsourced to service providers, but in any case produces new, additional costs that are not negligible.

3.4.3 Network change notification

Any network is a non-static environment requiring updates of the following: traffic capacity to be transported, new products requiring additional technical components, or software supporting new features, network optimisation, etc. Typically, the network operating software also requires upgrades to new releases in order to overcome weaknesses, improve network resilience or security, overcome software bugs, and add new features, etc. Some examples are given in section 4.

While some of these changes may be performed during regular network operation without affecting end-customer connectivity and service, many major improvements, especially major capacity enhancements, may affect the customers' individual access or network node within a region or across larger areas. Typical examples are those capacity enhancements described in section 1.1: fibre node splitting, migration towards RFoG, adding frequency channels, or the migration steps caused by smooth migration towards DOCSIS 3.1. Also, upgrading or exchanging a CMTS may affect end-customers.

All these changes are planned in advance. Thus, there is an opportunity to announce and coordinate this work with the wholesale-seekers in advance using a defined process. Such a process significantly differs from those processes reacting to faults. The coordination process could be comparable with the processes a network operator typically performs with its major business customers regarding planned changes, if such customers and processes exist (low probability for CATV network operators). In this case, an existing process has to be modified and expanded in line with the number of partners to coordinate with. Otherwise the coordination process should be developed and implemented from scratch. The communication can be routed via the intercarrier process gateway.

The key element is when the intended work has to be announced in advance. This may also be determined by the number of customers which might be affected. For example, fibre node splitting may have a shorter lead time than a CMTS exchange.

4 Network infrastructure changes

If a CATV network service provider intends to enter the wholesale access business without being forced to do so by any regulatory decision, the reason might be to fill available capacity in order to gain additional income. This is because an access network, once it is deployed, is a large block of fixed cost, which should be shared by as many users as possible. These operators are also willing to invest in additional equipment that is not an element of the mandatory functions in standardised DOCSIS (3.0) equipment. BSoD is one of these additional functions of interest for those operators that still have the capacity to support such services. Such services consume significant capacity, which is then no longer available for the other customers, e.g. for their own retail customers.

Sometimes providers are willing to incrementally expand the network if the additional business exceeds the costs. It might be that a few regionally restricted operators entering the market in a competitive way announce that they intend to offer Layer 2 services. These are latecomers and thus have a large economic interest in filling infrastructure and capacity using additional brands and therefore offer wholesale, mostly as bitstream.

Most of the well-established CATV network operators have upgraded their networks in order to support bidirectional telecommunications with capacity in line with demand from their own retail customers. In that case, they already have a good balance of capacity and demand. They are less motivated to increase capacity significantly (enhancing upstream/downstream frequency space, reorganising the radio and TV channels, buying and implementing BSoD features) in order to serve a few additional capacity-consuming (business or even VULA-residential) customers.

A telecommunication operator intending to buy wholesale access from CATV network operators of course has to expand its network in order to connect it with this new wholesale service provider. Also, depending on motivation and negotiation, the wholesale provider may approach the network of the wholesale-seeker.

4.1 Network topology and capacity

Network topology changes for the wholesale-seeker and the wholesale provider are determined to a large extent by the location of the handover points, the PoI. If the wholesale-seekers are taking over the traffic at the same network levels as they did before, there are no major changes to be expected in the network topology. If they change from a local handover (e.g. LLU) to a central handover of bitstream, the topology would change significantly because then most of the MDF-connecting network investment is stranded. If their change to a new wholesale provider is motivated by benefitting from the higher access bandwidth a CATV network can provide, compared to a copper pair access network, the additional capacity may result in network and network topology changes on the side of the wholesale-seekers.

If a wholesale access-seeker intends to locate its own network nodes in the collocation sites of the CATV wholesale provider, this might change the access-seeker's previous topology significantly. Such collocation is not very common, either because it is not allowed by the interconnection regimes or it is not efficient and results in a strong dependency on the wholesale provider. Vice versa, collocation of the hubs or higher network level nodes of a CATV network operator as the wholesale provider at the wholesale-seeker's node locations also results in a strong dependency relationship with the partner. Furthermore, changing the network topology of the wholesale provider typically is not very efficient, except when the companies shall be merged. These collocations of CATV network nodes and traditional fixed network nodes could be observed in the past where the telecommunication incumbent also operated the CATV network (e.g. still with TDC[25] in Denmark). Thus, for historic reasons, the node may be still collocated today, typically without using the CATV network access capacity for the traditional network operators, because the operators are now competitors and the CATV network operators are not open for the wholesale business at all.

CATV network providers offering new wholesale access services typically have sufficient capacity installed to transport the additional wholesale traffic; this means that only handover points have to be added. It may be that the capacity demand then grows faster than without the wholesale traffic and adjustments will have to be performed sooner (e.g. more powerful backbone with higher link capacity incl. new core node system and/or hierarchy, additional CMTS or CMTS capacity, frequency readjustment, fibre node splitting, DOCSIS release upgrade).

4.2 Physical access points

Wholesale business requires interconnecting the networks of the wholesale-seeker and the wholesale provider according to the wholesale products delivered. Bitstream is delivered at central sites, while local access is delivered locally. Where the CATV network is the wholesale-providing network, the local handover occurs at the CMTS or hub level. While bitstream just requires an interconnecting link between the networks, provided by one partner, local access typically requires collocation of the aggregating equipment of the wholesale-seeker. So additional space, or at least rack space, power including UPS, air conditioning and a fire alarm system, would have to be provided by the wholesale provider, which typically is paid for by the wholesale-seeker.

The interconnection link terminating equipment in the case of bitstream is either physically collocated at the wholesale provider's handover node location (link provided by the wholesale-seeker) or in the case of customer-sided collocation at the wholesale-seeker's

25 TDC, the national incumbent operator in Denmark, operates fibre based, copper based and CATV-based access networks in parallel.

node location (link provided by the wholesale provider). Both cases require adequate collocation conditions for the link termination equipment of the interconnection partner.

A wholesale access-seeker intending to access the wholesale provider's network at an amplifier level or even at a duct or fibre level has to deploy its backhaul infrastructure down to the locations of these infrastructure components. This requires large investment by the wholesale-seeker which shall only provide a return assuming high market shares can be achieved. This is another hurdle for entering such a business model, in addition to the obstacles mentioned in sections 2.1.1 – 2.1.3.

4.3 Backhaul

Issues associated with interconnection links and backhaul have already been addressed in section 4.2. Especially in the case of local access, the VULA access links could be backhauled over the wholesale provider's network to a more convenient handover point at a higher network level by mutual agreement.

5 Summary and conclusions

This study assesses whether it is technically feasible to provide wholesale broadband access services over a DOCSIS 3.0 CATV infrastructure. The investigations have concentrated on products in the new Market 3a and 3b defined by the European Commission. Since the investigations dealt with the options of uncontended bandwidth over Layer 2 access (for VULA) in the CATV network architecture, some results could also be used for analysis of Market 4, if CATV network operators are of relevance there (section 2.3).

Passive wholesale access products like empty ducts and free pole capacity or dark (unbundled) fibre are typically not available to the end-customers and not ubiquitously available in core and feeder elements of the network. They can be demanded only if topological congruence is given and so may be requested and offered on a case-by-case basis, but not as a general access business (see sections 2.1.1 and 2.1.2). Access to existing passive infrastructure may be regulated outside the market regulation (cost reduction directive and rights of way). One would have to analyse the existing duct and fibre infrastructure of the CATV network operator(s) in Ireland in order to assess if there are sufficient spare ducts, poles or fibres in a topology, and this is also of relevance (topological congruence) for other operators. At first glance, there is only a low probability of market contribution of passive wholesale access products by the CATV network operator.

Active virtual access products like direct amplifier access or frequency sharing and VULA are not practically feasible due to their complexity (direct amplifier access/frequency sharing, see section 2.1.3). This is because of the very limited capacity for only a few broadband access connections with an uncontended bandwidth character, especially in the upstream direction (VULA, see section 2.1.4). In addition, DOCSIS regularly does not support the Layer 2 (Ethernet) protocol typically associated with VULA because of its service-agnostic transmission behaviour, but operates with IP. A Layer 2 transmission standard exists alongside the DOCSIS standard, requiring DOCSIS as a prerequisite in CATV networks but not being part of it, namely BSoD. BSoD faces the bandwidth constraints of the downstream but even more of the upstream capacity (see section 2.1.4.2). In well-established CATV networks, there is no capacity left for VULA-like access services with dedicated and (in practice) uncontended bandwidth. A different option might be to have CATV network market entrant operators who still have to fill their network capacity and therefore intend to enter the wholesale market.

This situation will not change significantly when migrating to DOCSIS 3.1. First, the migration will be smooth and different DOCSIS releases will be operated in parallel in the same network. Secondly, the upstream capacity limitations exist here also, on a larger scale, but bandwidth demand will increase too. In addition, there is a trend towards more

symmetrical services, something DOCSIS in general is not really well designed for[26] (see sections 1.1, 2.1.4.4 and 2.3).

Thus, bitstream is the remaining Market 3 wholesale access product a CATV network operator can easily provide (section 2.2). Close control of network elements and functionalities and the close interaction of operational and business processes is not explicitly required for Market 3b wholesale products. Nonetheless, they would be helpful for entering this wholesale market, presuming the OSS enhancements required already exist to a wider extent or will at least be paid for by the additional income of the wholesale business.

In short, the OSS of a wholesale provider then has to support a multi-tenant environment, separating the access to the different operators' end-customers, protecting them from harm or erroneous disconnection. The OSS will require the capability to branch the processes by the wholesale-seekers, both internal and external ones. In an ideal form, it would be implemented in an EoI manner. The wholesale provider should offer an intercarrier process gateway operated to the greatest extent identical to the largest already existing interface in the market so that the wholesale-seekers can operate their wholesale business without major changes or differences. All automatic processes need these amendments when starting a wholesale business. Major effort will have to be put into a new operating process element ("change between retail operators", see section 3.2.4). While the OSS changes may become expensive and be a key reason not to start such business, the technical changes and amendments in the wholesale provider's access network are minor. Just some additional interconnection links and handover ports will be required (section 4). The additional wholesale traffic will increase, like all broadband access traffic, in the foreseeable future. This will result in earlier capacity upgrades being required than would otherwise be needed, i.e. without having wholesale traffic on top. However, as long as these upgrades are covered by the additional wholesale income, this will not hinder the wholesale business. There is an inherent danger that static or even decreasing pricing does not cover such capacity enhancements, as long as those benefitting from selling broadband access content do not pay for capacity upgrades themselves.

Outside Market 3, there is a potential wholesale business in Market 4 for a high-quality bitstream, which may be implemented as easily as the bitstream for Market 3b, but with some quality attributes (see section 2.3.2). In contrast, the typical Market 4 product of terminating segments of leased lines cannot be produced in a DOCSIS network either because it does not offer traditional SDH interfaces and SDH quality or because it is not capable of offering bidirectional symmetrical capacity of significant and sufficient size (see section 2.3.1).

26 The upstream/downstream relation is 1:10. Today, the relation is already 1:4 in CATV networks.

Consequently, one can expect only a very limited number of CATV network operators to be interested in a wholesale business, namely those that have recently invested in passive and active network infrastructure, and that still have spare capacity which can be sold because their own customers cannot fill it in a reasonable time. These operators typically have regional coverage only, thus will not be present on a national market, and they would be restricted to bitstream services in Market 3b and Market 4, if at all. These operators have to consider, if their BSS/OSSs allow for wholesale business in a multi-tenant manner already or if upgrades would make such business non-viable.

Annex A (Confidential)

Reflections on Virgin Media's installation in Ireland

[✂ [redacted] .]

Imprint

WIK-Consult GmbH
Rhöndorfer Str. 68
53604 Bad Honnef
Germany
Phone: +49 2224 9225-0
Fax: +49 2224 9225-63
Email: info(at)wik-consult.com
www.wik-consult.com

Person authorised to sign on behalf of the organisation

General Manager and Director	Dr Iris Henseler-Unger
Director Head of Department Postal Services, Logistics, and Transport	Alex Kalevi Dieke
Authorised Signatory Head of Department Cost Modelling and Internet Economics	Dr Thomas Plückebaum
Director Head of Department Regulation and Competition	Dr Ulrich Stumpf
Authorised Signatory Head of Administration	Karl-Hubert Strüver
Chairman of the Supervisory Board	Winfried Ulmen
Registered at	Amtsgericht Siegburg, HRB 7043
Tax No.	222/5751/0926
VAT ID	DE 123 383 795