DISCUS white paper:

Business and ownership models for future broadband networks

- **Dissemination level:**
  PU = Public

EXECUTIVE SUMMARY

DISCUS [1], [2], "The DIStributed Core for unlimited bandwidth supply for all Users and Services", is an EU-funded FP7 project whose goal is to exploit demonstrated technology and concepts needed to define and develop a new radical architectural concept that can enable an integrated wireless and FTTP future network which addresses the economic, energy consumption, capacity scaling, evolutionary, regulatory and service demand challenges arising from an FTTP enabled future.

In an earlier deliverable (D2.1) [3], which describes the proposed DISCUS architecture for future ubiquitous broadband provision it was stated that a major objective of the DISCUS project is to enable a future network that would tackle the three major problems facing today's network as it tries to respond to the huge growth required in network capacity that could arise over the next decade. These problems are:

- **the cost of network provision and financial viability of the telecoms sector**,
- **the huge growth in power used by the worlds telecommunications networks**
- **the need to avoid a "digital divide" being created between those customers in dense urban areas and those in the sparser rural communities, without the need for massive government subsidies**.

Solving such issues requires a radical change in the network architecture both from a technological perspective and from a regulatory and business model environment point of view. This has major implications for the regulatory policy, for the distribution and assignment of network resources at all layers and all users of the network, including the service providers, and for the nature of the ownership and business model structures that need to be supported.

The history of regulation in the wake of opening the incumbent dominated telecommunications network sector to competition was to focus on physical layer competition, particularly in the access network where the policy of Local Loop Unbundling (LLU) has been widely implemented. This was a very successful policy during that early era and because most of the network infrastructure, particularly the copper pair access network, was built from public funds, it was perfectly reasonable that other operators and service providers should get equal access to that existing infrastructure resource and avoid the need to build a parallel network at huge capital cost.

Despite the success of LLU in creating competition in the telecoms sector, from a customer or end user perspective the main benefit has been lower prices as the incumbents responded to the leaner competitors and became slimmer, leaner and much more commercial in their own operations and structure. However the ability to change provider, avoid contractual lock-in and select different services from multiple different providers at the same time has not occurred in the competitive market that has been created.

From a user perspective the ultimate solution should provide the ability to select, on the fly, any service provider for any service and have multiple service providers at the same time so that the users have the choice of avoiding contractual lock-in and can select the best offerings for their needs. They should have the option of only paying for what they use on a "pay as you go" basis" if this is desired. This would also enable a single network termination to provide multiple users in the same household, or office, the ability to have different service providers, even for the same services, if they wish to do so.

Another aspect of the DISCUS objectives is the "principle of equivalence" where the capability of the optical network termination is the same regardless of geographical location. The actual capability at the customer premises would depend only on the capability of the terminal equipment not the network serving the terminal. The network should be capable of delivering all services and capacities regardless of location of the customer. This would also allow service providers to locate and connect any where in the network and grow capability at that location, to 100Gb/s or greater capacity if they wish to. This would help stimulate service entrepreneurship, innovation and a much more competitive and dynamic service provision environment.

The aim of this white paper is to stimulate a discussion of network resource ownership options and the business models that could be supported. We first divide the type of services offered by operators/providers into three: passive infrastructure, active infrastructure and retail services. Then analyse the pros and cons of their potential ownership by entities such as: infrastructure provider, network provider/operator, service provider and, where suitable, end user/customer. The paper also examines scenarios where one operator provides more than one type of service, leading to totally or partially integrated models.

Our conclusion is that the favourite option is a partial vertical integration of the network provider/operator and the infrastructure provider in the access network. The competition is instead at the service level, which should become completely separated from the network infrastructure. This will require however stronger, clearer and more effective regulations, in order to ensure full open access and sharing of the infrastructure over all service providers and services.

A companion white paper was also published [4], discussing "Wavelength usage options in access networks".

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1 Introduction

This white paper and a companion paper on wavelength usage models are aimed at starting a discussion and debate on the regulatory and business environment that a future ubiquitous access broadband network should operate within.

There are three major problems that future networks must solve as they respond to the huge demand for network capacity that could arise over the next decade. These three problems are:

- The cost of network provision and the long term financial viability for the telecoms sector.
- The huge growth in electrical power used by the world's telecommunications networks.
- The need to avoid a "digital divide" being created between those customers in dense urban areas and those in the sparser rural communities, while minimising the need for government subsidies.

The FP7 project DISCUS [1] is proposing to tackle these problems with a network architecture that radically simplifies the network structure, rebalances costs from core and metro networks towards the access (by reducing network nodes - switching and routing centres - electronic traffic processing and port cards) and promotes sharing of large scale infrastructure and equipment to reduce per user costs. In addition to technical and network design solutions the DISCUS project also takes a fresh look at the regulatory and business model environment that network providers, network operators and service providers need to operate within as the network evolves.

In considering the business model and regulatory environment DISCUS focuses on the benefits from the customer/end user perspective while giving a fair return on investment to the network and service providers (SP) to encourage network investment. One aspect of this is to provide much greater availability of competitive service provision to customers without the long period contractual lock-in that happens too often today.

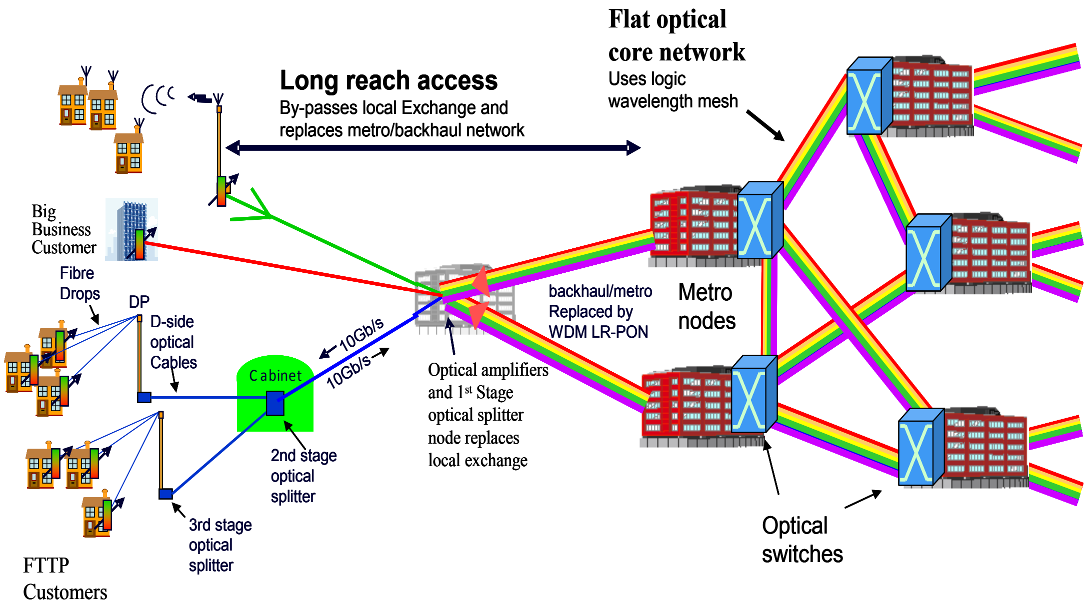

Figure 1 The end-to-end DISCUS architecture with LR-PON and flat optical core network

The DISCUS architecture, shown in Fig. 1 ([2],[3]) is based on large split and long reach passive optical networks in the access and metro networks and a flat wavelength switched core network interconnecting a relatively small number of traffic processing and switching nodes. The DISCUS Long-Reach Passive Optical Network (LR-PON) architecture is based on power splitters and uses optical amplifiers to overcome the power budget limitations. The use of power splitters provides the greatest transparency of the optical path between the metro-node where the LR-PON terminates and the customer premises termination and will also provide the greatest flexibility when wavelength division multiplexing (WDM) is used over the optical distribution network (ODN). The ownership and business models discussed in this paper are in the context of this network architecture.

In the companion white paper [4] the usage and ownership of optical wavelength channels is discussed. WDM will be an important technology to grow and enhance network capacity enabling more providers and content rich broadband services in the future. The use and ownership of the wavelength domain has major impact on the competitive, business and regulatory environments that the network needs to operate within. In this paper the complimentary ownership of network infrastructure and equipment and the effect on business models that can be supported as well as regulatory issues are discussed.

For this white paper the entities we are considering as potential owners of network resource, equipment and infrastructure are, as :

- **Network provider/operator:** The network provider would own and usually operate network equipment which is used to deliver connectivity to users and network services passing through that equipment. The network provider is therefore usually also a network operator (a provider could just be an owner of network equipment and lease this to a network operator if complete separation of the businesses id required). The operator would either be the incumbent operator or some other licensed operator (OLO). In the white paper we refer to "network provider" but it will usually means also a network operator.

- **The infrastructure owner (or provider):** We distinguish the infrastructure owner from the network provider by defining the infrastructure owner as only owning passive infrastructure, such as manholes, duct, street furniture, cables, fibre etc. They do not own network equipment including any electronic equipment housed in intermediate street furniture between the customer and the access network terminating node (the metro-core node in the DISCUS architecture or the local exchange/central office in today's networks). Of course a network provider could also own infrastructure but when we refer to an infrastructure owner/provider we are assuming a separated business.
- **The service provider:** These are users of the network that provide services to end user/customers (in this white paper when we refer to end users/customers we include all customer types, business and residential; even service providers - particularly small ones - are treated as customers in some business models). They can just offer content using network resources from the network providers, or they could offer additional services to support content distribution or other services e.g. a brokering service, authentication, billing etc. Although service providers can also own network resources, in this document we assume that they are not network providers unless we are specifically discussing issues of service provider ownership of network equipment and resources.
- **The end user or customer:** These generally would not own network equipment or network resources but they could own terminal equipment and this is discussed where it impacts on ownership models.

2 Network ownership models

This section discusses network infrastructure and equipment ownership models from the perspective of network provider/operator, network infrastructure owner, service and content provider and, where appropriate, the customer. In addition we will open a discussion on regulatory and competition issues. While it is obvious that these ownership models can be expanded by considering the permutations and combinations of these four business perspectives, we will only discuss those combinations that are more likely to occur and might affect the regulatory requirements of business models.

We consider the ownership options by starting with the customer premises equipment (CPE) and working deeper into the network comparing the pros and cons of different ownership and business models. To provide criteria for comparison we consider the ownership options from the perspective of the DISCUS architecture, which is predicated on:

- Infrastructure and network **resource sharing** (to reduce per customer cost)

- Equality of access so that any customer has access to the full range of network capability and services regardless of location: that is all services are ubiquitously available and **there is no digital divide**.
- The architecture should **foster an entrepreneurial spirit** and **encourage small start-up players to enter the market**. The aim is to enable new entrants to provide innovative experimental services, on a small scale initially, without requiring significant upfront investment for connectivity and capacity. If successful and the demand for these new services grows, bandwidth can be allocated in line with the demand and should only be limited by the capabilities of the CPE used by the new entrant.

Our basic criteria are therefore:

- There is **no duplication of network infrastructure and equipment** used to provide basic network services: that is there is only one fibre network for each customer premises for the mass of customers – (if it is difficult to economically provide one fibre network, it is probably impossible to provide more that one)
- As much as possible of the **fibre infrastructure (and network equipment) should be shared by as many customers as possible**.
- **Customers should have the option to access to multiple providers simultaneously** and be able to change providers "on the fly".
- Customers should have the option of bundled and fixed term contracts or have all **services provided from any provider at any time on a pay as you go basis** if desired
- There should be **no lock-in to single providers**.
- There should be **no physical hardware reconfiguration of network equipment, or infrastructure, required to change service provider -** all reconfiguration would be via software control of network equipment.

2.1 Customer premises equipment (CPE): the Optical Network Unit (ONU)

The network CPE which will be the ONU for Fibre-to-the-Premises (FTTP) networks could be owned by the customer, the network provider, or the service provider. It could also be owned by the infrastructure provider if that provider was also the network provider.

2.1.1 CPE owned by network provider

The usually assumed model for the CPE or ONU for optical networks is that the network provider will own the equipment. Reasons for this include:

- Interworking between different ONUs and Optical Line Terminals (OLTs – i.e., the equipment on the network end which terminates the optical signal from the ONU) for all service configurations is not always reliable and although standards bodies such as FSAN and BBF have tried to ensure interoperability between ONUs and OLTs from different suppliers it cannot be guaranteed that all ONUs from one manufacturer will work seamlessly with the OLTs from another for all service configurations. Therefore the sourcing of ONUs is often controlled by the network provider or operator.

- There is currently (2013) not a standard for an optical Network Termination Equipment (NTE) into which a generic and adaptable ONU could be plugged by the end user (the NTE defines the edge of the operator's network and the edge of the customer's network. It is often a legal demarcation point defining the boundary of responsibilities). The ONU can perform this function when owned by the network provider.

The advantages of the network provider owning the ONU is that it removes a financial barrier to take up of FTTP provisioning as the upfront cost of the ONU is borne by the provider. The network provider will ensure compatibility with network equipment and operations, as well as being responsible for maintenance issues.

If the network provider delivers open access connectivity [5] (i.e., allows fair access to the network for customers and service providers) then ownership of the ONU should not limit service provider competition. While future access networks will invariably evolve to operating with multiple wavelengths [6], the protocol running over the PON can deliver all services from all providers through a low cost single wavelength ONU fixed wavelength transceiver. This will help to minimise entry costs. As requirements grow the ONU can be upgraded to a tuneable or even a multi-wavelength capable device at a later stage.

Disadvantages of ownership by the network provider or operator include:

- The network provider will wish to minimise changes and upgrades so evolution of ONU functionality may be slower.
- The network provider or operator has to recover the cost of the ONU which will make the business case for FTTP more difficult. However the ONU (and the final optical drop) is a "just in time" (JIT) expenditure and is only incurred when a customer requests service and revenues are generated. Thus, unlike upfront infrastructure and network equipment cost, it is lower risk and has minimal negative impact on return on investment or time to positive cash flow.
- Depending on regulation for telephony and emergency access, the network provider will be responsible for battery back-up of the ONU and also maintenance which increases operational cost.

2.1.2 CPE owned by service provider

Here we assume the service provider is separate from the network provider or operator. Where the service provider is also the network operator the previous discussion applies. However the case of ownership of the ONU by the service provider may restrict open access to other service providers and would not be a preferred model.

The issues associated with the ownership of the ONU by the service provider depend heavily on the wavelength usage model for a shared multi-wavelength PON solution as proposed within the DISCUS architecture [4]. If the wavelength usage model is a wavelength per service provider model, then an ONU offered to a customer by a service provider would almost certainly be part of a bundled contract. The service provider would probably provide a fairly basic low-cost ONU with a fixed transceiver operating at its assigned wavelength, as it would have no incentive in offering an ONU able to work with other providers. This would lead to contractual lock-in and a less competitive broadband market, as moving to a different SP will likely incur penalty costs and longer delays because the user will need to replace its CPE.

If however wavelengths carry services form any service provider and also all service types then an ONU can in principle receive services from any service provider. In this case the service provider would use ownership of the ONU as part of a contractual bundle for a fixed period contract for services. It may place restrictions on the ability of the ONU to deliver services from other service providers, that is it would be locked in a way analogous to mobile phone locking. However it is assumed the ONU could be unlocked at the end of the contract period and the ONU used to connect to services from other providers.

There are indeed operational issues with the service provider owning the ONU. For example, will the service provider be responsible for maintenance; will they be responsible for emergency service provision, battery back-up? It is probable that the ONU ownership model would be more like the mobile phone model and although the phone is provided by the service provider the owner effectively is the customer and the customer will be responsible for maintenance, battery back-up etc.

ONUs with tuneable transceivers would be advantageous even in a wavelength usage model where the service provider "owns" or is assigned a wavelength for sole use. The actual wavelength can then be assigned to the SP by the network provider and a service provider might be assigned different wavelengths in different PONs or metro-core nodes. Tuneable ONUs would mean that any ONU could be used on any wavelength by any service provider by just tuning it to the appropriate wavelengths during installation and registration. It is unlikely that SPs will have interest in providing a multi-wavelength ONU unless a wavelength usage model where wavelengths are assigned to services is implemented (i.e., service providers operating simultaneously on multiple wavelength channels, see companion white paper [4]), for other wavelength usage options any additional channel would probably be used for services from other competitor providers.

To summarise, if the service provider owns the ONU, it is likely that contractual lock-in will occur and competition will be poorer. The ONU will also probably be locked for some time to the original service provider making it difficult for the user to change provider. To stop such restrictive practices a strong regulation would be needed to ensure customers can access competing providers.

2.1.3 Customer-owned CPE

The option where the customer owns its CPE would have the least restrictions on competition. The main economic issue with customer-owned ONU is the additional cost that has to be borne and may constitute an entry barrier for some customers, thus reducing take-up. The customer will also be responsible for maintenance and any battery back-up capability if required. In addition a standardised network termination is required, into which the ONU can be plugged by the user. The cost of the ONU will depend on the functionality required, which in turn will depend on the wavelength usage model being used over the PON. For example if wavelengths are assigned to the service provider then the customer would need a tuneable transceiver in the ONU to change provider. Similarly if wavelengths are assigned to service type then a multi-channel tuneable ONU would be required. If instead the wavelengths are shared by service providers and carry all service types then the customer could buy a simple fixed-wavelength ONU and still get access to any service provider and service at any one time.

A disadvantage of customer ownership might occur in some cases as the network grows and evolves and new wavelengths are added to the PON. The network operator may need to move customers from highly loaded wavelengths to new wavelengths to balance the load across wavelengths and OLTs. Those customers owning a fixed-wavelength ONU may incur lower service quality (unless they purchase a new tuneable ONU) as the operator will not be able to reconfigure their ONU to work with a different OLT or wavelength. Another issue with customer-owned equipment is that ONUs will need to have a certification of interoperability, which could be expensive and problematic due to multi-vendor competition. In addition this will make it easier for un-certified CPEs to be connected to the PON, possibly interfering with or even interrupting the service of other ONUs.

On the other hand, customer ownership of ONU may stimulate a more dynamic market place for combining other CPE functions and ONU development with a varying range of features and capabilities. This will also minimise the issue mentioned above, as it will incentivise periodic upgrade of the ONU. Finally, customers requiring very high capacities, such as large business customers or service providers connecting to the core via the PON network, could purchase multi-wavelength ONUs with the appropriate capability (i.e., working at rates of 40 or 100Gbps, where allowed by the PON architecture).

2.2 Passive network access infrastructure

Passive network infrastructure includes ducts, fibre cables, casing splitters and wavelength multiplexers, if placed within the network (in this white paper we have assigned ownership of active equipment within the access network such as reach extenders or optical amplifiers to the network provider/operator). Network placement of WDM multiplexing devices is not preferred in the DISCUS architecture as it restricts the allocation of wavelength channels across the customer base, although it is an option to be considered for some wavelength bands.

The passive network infrastructure could be a separate business from the network provider or operator. One scenario of an architecture providing full separation would see the network provider leasing infrastructure from the infrastructure provider to build and configure its required network. Service providers would provide their services to the end users by leasing or having capacity assigned to them via the network providers. Separation of the infrastructure from the network provider is seen as a way of encouraging new entrants and competition into the access network provision market.

However there are problems in opening up this sector of the market: fibre to the premises is financially challenging and needs to gather revenue from as many users as possible to speed up the Return on Investment (RoI) on the infrastructure. Opening up the infrastructure to a number of competing network providers at the physical layer, installing their own competing infrastructure, will fragment those revenue streams making it even more difficult to get a financial RoI. This problem is being tackled within the DISCUS project by designing an architecture that maximises sharing of a single infrastructure over as many customers as possible by using a high-split LR-PON that has a fibre lean optical distribution network that minimises fibre cable and infrastructure investment.

An infrastructure provider would however need to pre-provide infrastructure and estimate the size of fibre cables without a detailed knowledge of the topology and architecture to be built for prospective network providers. This would almost certainly result in over provisioning of infrastructure in order to service potential parallel competitive networks, which would mean higher cost and therefore higher leasing prices to network providers. A further problem arising from multiple network providers and operators having parallel infrastructure leased from an infrastructure provider is that there would also invariably be an over provisioning of network equipment and unnecessarily higher costs and energy consumption.

However even if the competition model continues to be based on physical layer competition, the idea of allowing only one infrastructure provider would have the advantage that only one entity (i.e., the infrastructure provider) would handle the physical infrastructure. This would minimise intervention faults introduced by multiple-parties entering manholes, opening splice housings and generally disturbing other operators' fibre systems.

Infrastructure ownership by the service provider is the equivalent of today's typical scenario with vertically integrated incumbents owning both access infrastructure and service provisioning. This would require strong regulation, much beyond the principles of local loop unbundling used today for the copper network, if a truly open-access and competitive model without customers locked into long contracts is to be realised.

Infrastructure ownership by the network provider or operator may be more likely to realise the most efficient infrastructure as the fibre and cable build would be optimised to minimise first installed costs. This however will require strong and clear regulation to ensure full open access and sharing of the infrastructure over all service providers and services.

The case where the end user owns fibre infrastructure external to their premises or campus is not applicable to fibre architectures. If for example the customer installed and owned the fibre drop into their premises it would simply move the legal demarcation point between the customer's network and the operator's network from a point in his premises to a point outside. There would also be issues about ownership of infrastructure that goes beyond their property boundaries. These issues effectively rule out customer ownership of external infrastructure.

To summarise: the DISCUS architecture can support all the infrastructure ownership models discussed above but the most efficient, at least for first installed costs, would probably be ownership by the network provider as that would lead to the leanest and lowest up front cost infrastructure provision. However it is recognised that a strong regulatory environment would be required to ensure full open access.

2.3 Active network access equipment

The active equipment in the access network and terminating network node (the metro-core node in the DISCUS architecture) would typically be owned by the network provider. However there could also be options for some elements of network equipment to be owned by service providers.

Ownership by the network infrastructure provider is a contradiction in terms as once the infrastructure provider begins to own the network equipment they would become a more vertically integrated network provider.

Ownership by the end user is also unlikely as there is no reason for the customer to own network equipment that other users would utilise. It might be possible for large business customers to own equipment for private networks, however this would be unusual as private networking is more likely to be provided by leased capacity or by software defined and virtual networks in the future – such networks could be defined both by a full wavelength channel or capacity assigned with a wavelength to a virtual network link.

We now examine the pros and cons of ownership of some network equipment by the network provider/operator and the alternative of the service provider ownership. Again for this paper we discuss the ownership aspects from the point of view of the DISCUS architecture and to aid the discussion an example of the LR-PON access network connected to a DISCUS metro-core node is shown in Figure 2.

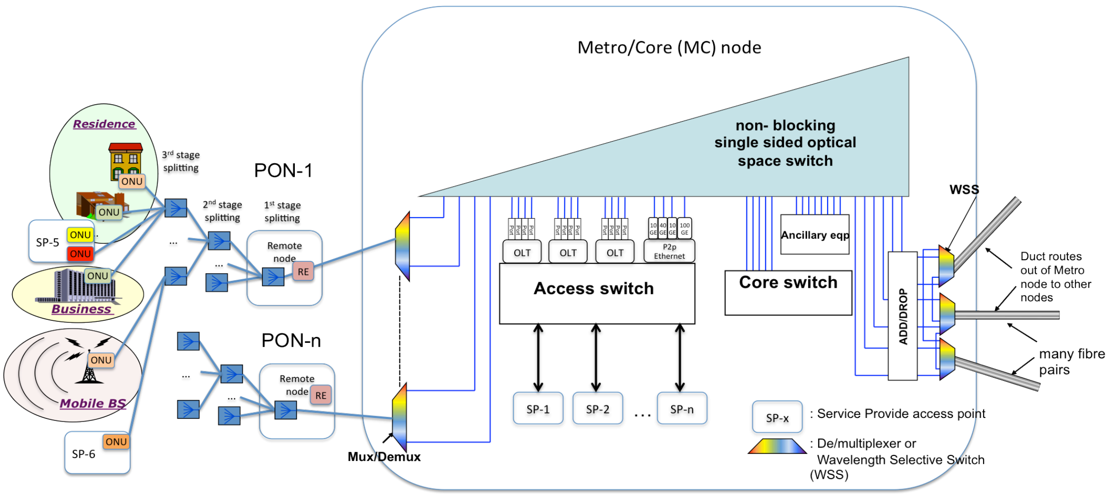

Figure 2 Example of Metro/Core node considered in the LR-PON DISCUS architecture

2.3.1 Reach Extenders (RE) ownership

For the LR-PON architecture a reach/optical split extender is usually required within the access network. This would usually be placed at the old local exchange site, which is by-passed in the DISCUS LR-PON architecture. Generally an optical amplifier is used, although in some cases it could include a regenerator.

The reach extender (RE) would usually be owned by the network provider. This solution makes the RE a transparent node that does not restrict open access and can be shared by all customers and service providers using that network provider. Competing network providers would provide their own REs, making this scenario compatible with all wavelength ownership and business models described.

Ownership by the service provider only works when single-wavelength amplifiers are used and wavelengths are assigned for the sole use of a service provider. However this only makes sense if the service provider also owns the transmission infrastructure at the network termination (i.e., the OLTs). The problem here is one of wavelengths management since the operation of each amplifier could disturb other channels in a WDM system. This ownership model is also incompatible with the more open and efficient wavelength sharing option where service providers share access wavelength capacity. Indeed, if the Service provider owns such network equipment this makes it a vertically integrated network provider as well as service providers and a regulatory framework would be required to ensure open access and prevent restrictive practices. Single wavelength amplifiers would also have higher power consumption and cost.

2.3.2 OLT

OLTs are normally designed into blade cards containing between 8 and 16 transceivers (depending on their rates). The cards plug into a shelf which provides a switching backplane and data aggregation point. Such shelves can in some cases also function as the access switch. We often use the term OLT when referring to a single PON head end terminating port, which consists of a single transceiver and the associated protocol circuitry and back plane or network interfaces.

Where wavelengths are assigned to service providers, single-PON OLTs are used solely by a service provider and therefore could be owned by them. However ownership of one PON OLT on an OLT blade would be problematic and a much better option would be for the service provider to lease it from the network provider, which will own and maintain the OLT shelf (although a large service provider might indeed own an entire shelf). Owning an OLT allows the service provider to have full control over the capacity allocation to its customers. If the customer has a fixed-wavelength ONU then the customer would be locked to the service provider that owns or leases the OLT corresponding to the customer's wavelength.

The case where the OLT is owned by the network provider is instead compatible with all business and wavelength usage models. Indeed the ability to lease capacity to all available services and service providers constitutes a more competitive business model, leading to open access and wider competition.

An additional reason in favour of network provider ownership is that of network protection. LR-PONs used in the DISCUS architecture are dual parented onto two metro-nodes. The protection mechanisms would struggle to operate correctly if the management and control of the OLTs becomes fragmented due to ownership by different service providers. Finally, the network provider ownership model can also be more efficient, as it can avoid full duplication of active OLTs and use a share protection mechanism for OLT protection rather than a 1+1 protection, which would reduce both cost and energy consumption.

2.3.3 Fibre and access switch

The optical circuit switch and the electronic access switch are shared between multiple OLTs and service providers and therefore would be owned by the network operator. This would ensure equality of access to network resources and minimise restrictive practices, although it may be necessary to have appropriate regulation to ensure that network providers will offer fair and open access products and services. Service provider ownership of the switching equipment would lead back to the vertical integrated operator scenario and offers no competitive advantage.

2.3.4 Service provider and other network operator access points

A number of different options are available for service providers to access the metro core node, which lead to different ownership models for the service router infrastructure. Some service providers may only be interested in providing content to the users, without regulating and authorizing their access to the Internet. These service providers could locate content at each metro node or else distribute it from a centralized location, and enter the metro-core node through a core network fibre link. In this case service routers are owned by the network provider, together with the access switch (they might even be embedded in the switch).

Another possibility is for the service providers, or indeed other network providers, to own service routers. These could be located at each metro node, placed at a large centrally located data centre or at a remote location. Hybrid models are also possible where larger service providers might own their own service router, while other smaller providers might share capacity on a shared router owned by the network provider/operator.

A further possibility that could be used to stimulate some competition in the network provider domain could be to have franchised areas where an operator would for example run a metro-core node area owning the access equipment, optical switch and layer 2 access switch but would also have other providers equipment such as service routers and/or core network equipment within the metro node connecting to the layer 2 access switch.

Another interesting option, valid especially for the more flexible shared wavelength business models, is that service providers could access their users directly from the ODN side of the PON via an ONU. Instead of renting dedicated fibre to reach the MC node, they could share the ODN access fibre with other broadband users, and, depending on their requirements, either be assigned a certain capacity over an existing PON wavelength, or else avail of a dedicated wavelength channel. This is illustrated in Figure 2 on the left-hand side by SP-5 which has been allocated two dedicated wavelengths, and by a smaller SP-6 which instead has been assigned capacity (for example a 1Gb/s assured rate) over a shared PON channel.

3 Summary

This section summarizes our discussions for the different ownership and business models. Essentially there a three general business model structures discussed:

1. **Separation of the business operations and ownership** into: a service provision business, a network provision/operation business and an infrastructure provision business.
2. **Business structures where some level of vertical integration occurs** between these three ownership/business models. For example the fact that the network operator could also own the access infrastructure, or the service provider own the OLT etc.
3. **The sharing versus ownership**, by the three entities, of network resource (such as optical wavelengths over the access network) and its assignment to end users and service providers.

As mentioned in the introduction the objective of the DISCUS project is to devise an architecture that tackles the three major problems facing future ultra fast broadband networks, while encouraging service provision competition and enabling customers to access any service from any provider at any time. The aim is to achieve these objectives by minimising equipment and infrastructure build, while maximising sharing of network resources.

The business models most compatible with these objectives are the partial vertical integration of the network provider/operator and the infrastructure provider at least for the access network, optical switch layer and the access switch in the metro-core node. There would be complete separation of the service provider business, although ownership of IP layer service routers by service providers would also be compatible with such objectives.

The preferred model for network resources would be full wavelength and resource sharing so that service providers would be assigned capacity on demand and a customer with a simple single wavelength ONU could obtain simultaneous access to multiple service providers for any service at any time: that is using the time domain for dynamic bandwidth assignment and the wavelength domain for capacity management. However this level of vertical integration would need strong regulation to ensure no restrictive practices limiting open access can be implemented and that all service providers get fair access to customers and capacity.

As far as ONU ownership is concerned end-user ownership or the network provider ownership models are most compatible with open access and service competition. Service provider ownership is instead the model that leads to less competition as it enables locking of the ONU to the provider and should be avoided if possible.

Network provider ownership of network equipment has the advantage of allowing the active equipment to be controlled by the same entity, with better management, better utilization and protection against failure. Multiple operators competing in the access network and optical and layer-2 switching space come at the expense of a less efficient network, due to duplication of equipment from different providers. Multiple network providers serving the same customer base could also restrict customer access to service providers as those service providers using only one or a subset of network operators would not be able to access customers connected via the other competing network providers. A fairer and better economic solution would be a single network provider owner but with a strong and knowledgeable regulatory environment to ensure fairness and value for money pricing. However to have some level of competitive comparison at the network provider level a franchising system could be implemented where a network provider operates the access and metro-core node in a given geographical area, similar to the way cable operators have had franchise arrangements.

Finally, ownership of service routers is both viable for service providers and competing network providers/operators. One advantage of network operator ownership is that it can lower entrance barriers for small service providers, which in this case do not need to own their own service router. Lowering the entry cost barrier for small start-up service providers could play a major role for the development of novel future applications and services. A flexible high capacity access network as proposed by the DISCUS project, when combined with efficient business models like the shared resources and infrastructure can lower such barriers, as new service providers can share capacity and access cost with other users, keeping initial investment costs low and enabling a “pay as you grow” business model for start-ups.

In conclusion we would propose a sharing economy approach to future network provision and operation with appropriate regulation which together will maximise open access and competition for services while minimising cost for users and the risk of a digital divide and also to minimise the cost for innovative new start-up service providers to obtain access to network capacity and services and an extended customer base.

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Abbreviations

BBF	Broad Band Forum
CPE	Customer Premises Equipment
EU	European Union
FP7	Framework Program 7
FSAN	Full Service Access Network
FTTP	Fibre-To-The-Premises
JIT	Just In Time
LLU	Local Loop Unbundling
LR-PON	Long-Reach Passive Optical Network
NTE	Network Termination Equipment
ODN	Optical Distribution Network
OLO	Other Licensed Operator
OLT	Optical Line Terminal
ONU	Optical Network Unit
PON	Passive Optical Network
RE	Reach Extender
RoI	Return on Investment
SP	Service Provider
WDM	Wavelength Division Multiplexing