Gigabit technical playbook

NOKIA

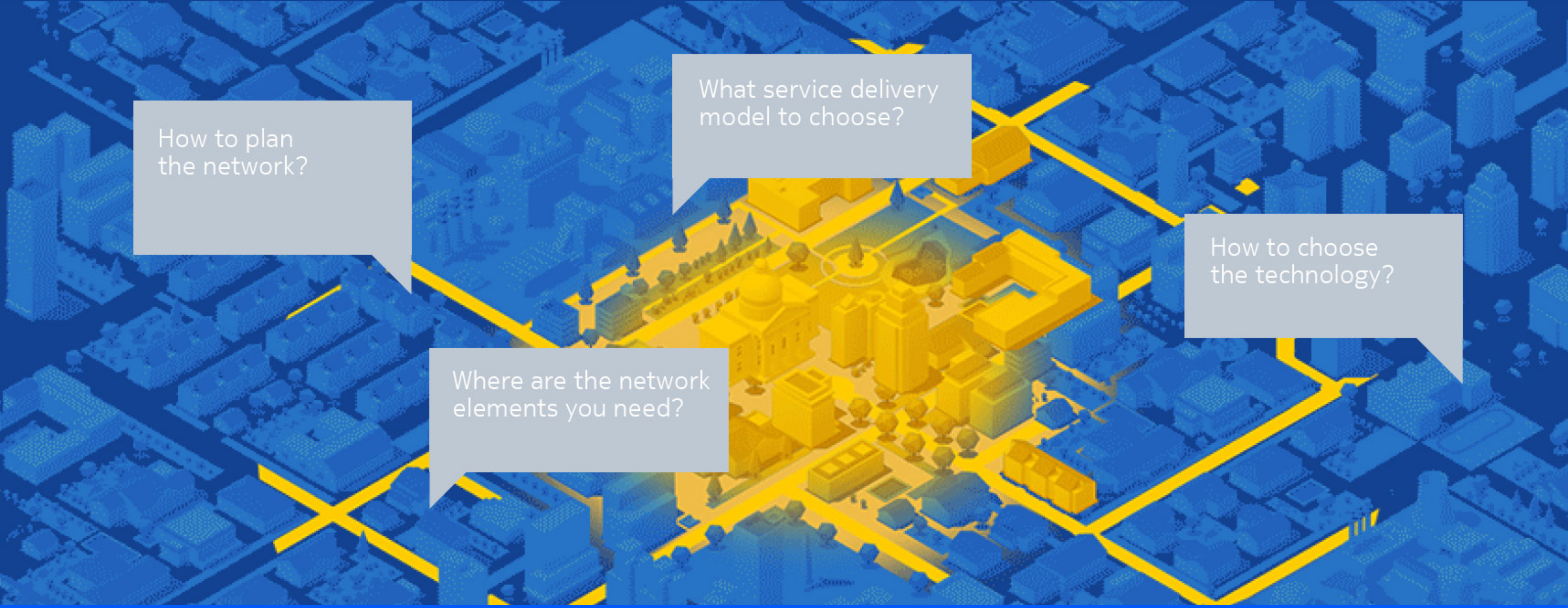


Figure 1. Technical considerations in utility broadband projects

These are just a few of the questions that network providers planning broadband services offering are considering. As a worldwide leader in gigabit broadband and with a long history of shaping the world's telecommunications landscape, Nokia can help you answer these questions. This playbook takes a look at the primary technical considerations for how open access broadband networks can be achieved.

Index

1	High-level network overview	4
2	Network planning	8
3	Network build-out	21
4	Active equipment deployment	26
5	Network operations	29
6	Nokia broadband offer	32
7	Secure success with a proven partner	38
8	Acronyms and terms	41

1 High-level network overview

Gigabit broadband is about building an infrastructure for economic growth and new investment opportunities. Driven by relentless users' appetite for high speed services, investments in fiber to the home networks (FTTH) are being made by Communication Service Providers and various new players: utilities, real-estate investors, governments, private equities and others. To optimize the business case, they are evaluating different options to accelerate FTTH deployments, share investment and risk and increase service adoption. The infrastructure network providers increasingly turn to open access networks to meet their business goals.

There are three basic levels in a broadband network, and a communication service provider may only need one or all three.

- **The access network** connects residences and businesses to access nodes where the first traffic aggregation takes place
- **The aggregation network** combines traffic from multiple local access nodes and sends it further up into the network. It is sometimes referred to as a regional, metro or backhaul network
- **The core network** connects traffic from different areas, municipalities or regions. It is sometimes referred to as a backbone network.

For areas of a modest size, a broadband network can be as simple as a few access nodes and a software platform to manage the broadband services for each user. But in many cases, open access broadband networks will also include aggregation and core networks, providing more complex network functions. The decision will be driven by things like the size of the network, the geographical area to be covered, and the interconnection point with a national network.

The aggregation network typically contains aggregation access nodes. The core network includes service routers and transmission switches. Service routers are used to forward data packets between different networks. A data packet is usually forwarded from one router to another until it reaches its destination. The service router enforces per-user, per-service provider, and per-service rules to ensure that the right quality of service is applied to each user according to the service level agreement. Service routers can also function as full broadband network gateways (sometimes called edge routers) if retail-type services are being provided. In this case, the service router serves as a hand-off between two networks.

The topology of aggregation and core networks can be as follows.

- **Tree.** Traffic is aggregated upwards in a hierarchical manner. It is cost-effective but not robust
- **Ring.** Every network element is connected to two elements, so that all connections form a ring. It is more secure in case of faults, but more expensive
- **Meshed.** Each network element is connected to several other elements. This is the most robust but also most expensive and complex
- **Mixed.** It is also possible to combine tree, ring and meshed. For example, tree for residential, ring for businesses and meshed for critical businesses (e.g., hospitals and data centers)

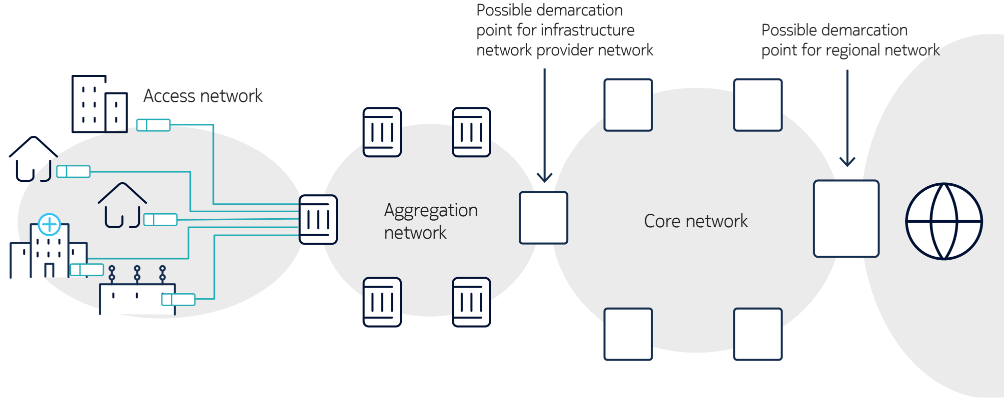


Figure 2. High-level broadband network topology

1.1 The access network

The access network is where subscribers are connected into the network via an access node. There are several fixed access technologies that can be used in an access network, depending on the physical medium used to connect subscribers (copper, optical fiber, coaxial cable). This playbook focuses on optical fiber used in a fiber-to-the-home (FTTH) network as it is the most common choice for utility broadband deployments.

The access network may connect some or all of the following:

- Residential users
- Businesses, schools, universities, hospitals and other organizations
- Mobile network base stations and antennas
- Public security structures, such as sensors, surveillance cameras and alarms.

In an FTTH access network there are two end-points with **active** (i.e., powered) electronic transmission equipment, connected by **passive** (non-powered) equipment known as outside plant.

- One end-point is at the subscriber's premises, where an **Optical Network Termination** (ONT) device is installed and connected to various home devices like a PC, TV or set-top box, phones, and Wi-Fi devices like tablets and smartphones. The ONT is a demarcation point between the home network and the operator network.
- The second end-point is the access node, called the **Optical Line Termination** (OLT) point, typically located in a central office or a cabinet in the field. The role of the access node is to aggregate connections from multiple users and connect them to the aggregation or core network.

The outside plant consists of various passive components, including:

- Optical fiber cables
- Splitters that allow the signal from the access node to be shared between several users
- Duct or micro-duct systems containing the fiber-optic cable
- Fiber splice enclosures
- Drop cables, which are installed when a subscriber signs up for service
- Network access points or terminal points to which drop cables are connected
- Optical distribution frames used to organize fiber-optic cable connections.

In the outside plant, the distribution network (also known as the feeder plant) runs from the access node to the main fiber connection and may cover several kilometers.

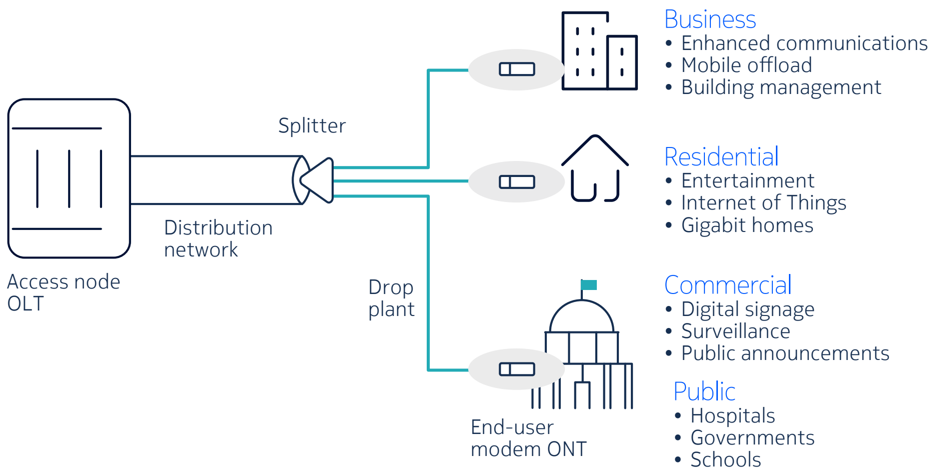


Figure 3. Point-to-multi-point fixed access network

The connection to homes and businesses is known as the **last mile**. This can have two basic topologies.

- **Point-to-multipoint** (P2MP). The access node connects a number of users over the same shared medium using one transmitter, as shown in Figure 3. The total available bandwidth is shared between all users. This approach is widely used in wireless (for example, 3G and 4G networks) and wired communications (passive optical networks and cable networks). In passive optical networks, a splitter is used to divide the signal from fiber feeder into output branches
- **Point-to-point** (P2P). The access node connects a number of users but each with a dedicated connection using a corresponding number of transmitters. This approach is used in radio communications, copper-based broadband technologies (xDSL) and Ethernet point-to-point.

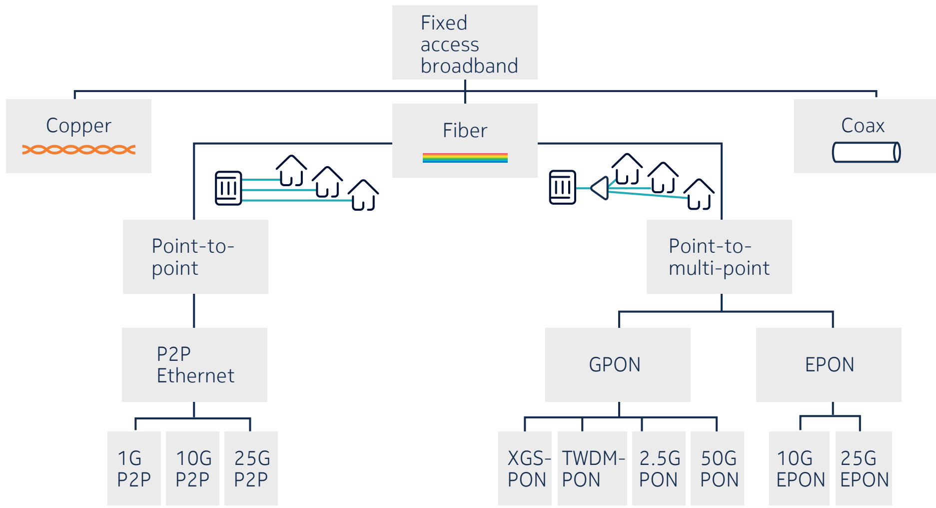


Figure 4. Overview of fiber access technologies

2 Network planning

Large FTTH investments require careful planning to minimize the cost and risk. Good planning is essential to a successful business case. Throughout the planning and business case development process, an understanding of how economic, legal, political and business drivers impact the economics of deploying and operating a broadband services network needs to be developed. Here we shall consider the technology.

When modeling network economics, many parameters need to be taken into consideration, and it is important to identify the most sensitive parameters that are critical to the decision-making.

Network planning consists of different phases.

- **Strategic network planning** creates several important outputs: the business case and major strategic decisions, such as which technology and what type of outside plant will be deployed
- **High-level network planning** creates the lowest-cost network design within the boundaries of the strategic planning and geographical area where the network will be built. The outputs of this phase include the construction strategy, redundancy paths to protect against failure, demarcation points between network provider and end user, preliminary bill of materials, points of presence (POP), and distribution points

- **Detailed network planning** provides tailor-made network drawings with all connection details and documentation that will be used during network build-out and operations.

To generate a good network plan, every decision should be based on a clear vision of which services will be offered, how the network will operate, the deployment and operation costs (CAPEX/OPEX), accurate geographical and other local data, and technical details of the network's capabilities (material specifications, capacity requirements, reliability requirements, etc.). Collecting this data is crucial to ensure that the right decisions are taken as early as possible. However, corrective decisions may be necessary as the project progresses and new information becomes available.

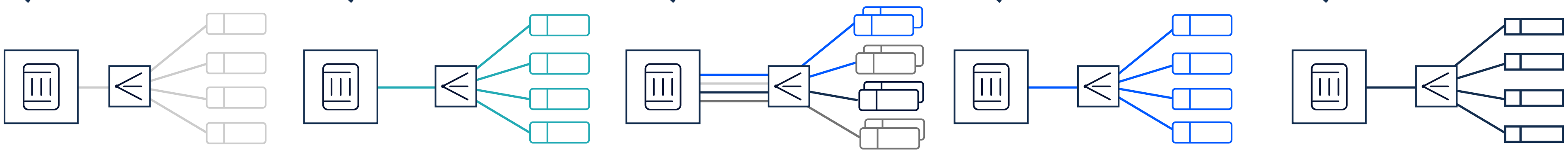
New players entering into the FTTH open access network opportunity should rely on industry experts and software-based planning tools to process the data, create scenarios with different assumptions, compare the results and select the optimum proposal, and create the detailed build plan documentation.

2.1 Technology choices

One of the most important choices in the broadband project is between Ethernet P2P and passive optical network (PON) technology. Both technologies have their merits and have been deployed in utility broadband networks. However, PON is far more dominant in today's FTTH deployments.

In a PON network, the outside plant is much more economical to operate as it is completely passive: it does not require power supplies, batteries, electronics maintenance or upgrades. Over the years, technological advances in fiber, enclosures, fiber management cabinets, splitters, fusion splicing and active equipment have optimized PON to enable the density and flexibility that is required in large-scale deployments. Today, PON is the fastest growing access technology. There are several types of PON.

GPON	XGS-PONT	WDM-PON	25G PON	50G PON
Gigabit PON	**10G symmetrical PON**	**Time wavelength division multiplexing PON**	**25G symmetrical PON**	**50G PON**
2.5 Gb/s **1.2 Gb/s**	**10 Gb/s** **2.5 or 10 Gb/s**	**4 x 10 Gb/s** **4 x 10 Gb/s**	**25 Gb/s** **10/25 Gb/s**	**50 Gb/s** **25 Gb/s**
Enabler of Gigabit broadband.	Dual rates: symmetrical or asymmetrical. Co-exists with GPON, TWDM-PON, 25G PON	Uses 4 wavelength pairs (4 in upstream, 4 in downstream). Multiple users share a wavelength pair.	Dual rates: symmetrical or asymmetrical. Co-exists with GPON, XGS-PON, TWDM-PON, 50G	Asymmetrical. Co-exists with GPON, XGS-PON, TWDM-PON, 25G PON
The widest deployed PON technology worldwide since 2007.	Now the main PON flavor being installed today, worldwide.	Limited deployments	Trials and pilots, some deployments started.	Research, prototypes.



GPON (Gigabit Passive Optical Network) is the global technology of choice for delivering super-fast broadband services. Successful open access broadband projects that started with GPON technology include EPB Chattanooga, Bolt Fiber Optic Services, LUS Fiber, Chorus, nbn, Open Fiber, KPN etc. Major service providers, such as AT&T and Verizon, also use GPON technology.

Here are some key facts about GPON.

- GPON is very fast. Data from the access node is transmitted at the speed of 2.5 Gb/s
- GPON is a shared technology, meaning that a single fiber-optic cable is used in the distribution network, and somewhere close to users a passive splitter fans out multiple fibers to share the bandwidth between multiple users in a group (typically 32 users)
- This type of network requires few active components which, compared to active technologies, results in lower costs and complexity, less power consumption and floor space in the central office, and simplified management
- GPON has a long reach and can cover large areas. Hundreds of users can be connected from a single access node, which reduces the cost of deployments and is especially important in lightly populated areas
- GPON allows dynamic bandwidth allocation. This means that broadband speeds provided to each user can vary automatically depending on usage demand. For example, when a user download a large file or movie, a burst of increased speed will provide faster download and a better user experience
- GPON is future-ready because it can easily be upgraded to next-generation technologies without the need to change anything in the most valuable part of the network — the fiber plant. For example, by introducing XGS-PON electronics at both end of the network (at OLT and ONT side), the network capacity can be increased 4x using the same fiber infrastructure.

Ethernet point-to-point technology provides a direct and dedicated fiber connection from the Ethernet switch (access node) to a single household or business. The Ethernet switch is usually located in the central office, but could be placed somewhere deeper in the network (a roadside cabinet or basement of a building, for example), although this adds complexity and operational costs. Today, most Ethernet P2P networks deliver 1 Gb/s to each user and can easily evolve to 10 Gb/s. However, the operational costs of P2P networks are higher than GPON. Since every user has a dedicated fiber connection, P2P networks have more fibers and larger ducts (pipes); require more maintenance and more equipment in the central office (more floor space, more power consumption); and take longer to repair in case of cable cuts or other problems.

2.2 Network capacity

In light of continuous traffic growth, network providers need to make smart decisions about network capacity. Underestimation leads to poor network performance, customer dissatisfaction and the need for new investment cycles. On the other hand, overestimation leads to overinvestment, which ties up capital that could be used elsewhere.

To calculate network capacity, current and future user demand need to be considered and where that demand could create bottlenecks in the network.

Nokia has developed a unique bandwidth-modeling tool to help network providers make informed decisions about network capacity. Based on our global experience, the tool forecasts aggregated bandwidth demand in fixed networks by assessing user traffic patterns, consumer behavior and service evolutions.

Some facts about bandwidth demand trends.

- There are two types of user traffic: sustained and burst
- Video is by far the biggest component of sustained bandwidth demand (for example, pay TV, video on demand, and over-the-top internet video such as YouTube and Netflix)
- Speed tests and file transfers are the biggest contributors to bursts in traffic, creating peaks in bandwidth demand.

Network capacity calculations need to consider both traffic types. Although the demand for upstream capacity is increasing, overall traffic patterns are asymmetrical (i.e., more bandwidth is required for downstream traffic than upstream).

In access networks there are three points that can potentially deteriorate the service delivery performance:

1. **The last-mile connection to users.** The available bandwidth for users is determined by the access medium (e.g., copper or fiber) and the transmission technology (e.g., xDSL or GPON). Fiber as a medium has virtually unlimited bandwidth potential and current FTTH technologies, either PON or P2P, are designed to allow high speeds. In point-to-multipoint networks like GPON, the total available bandwidth is dynamically shared between multiple users and this will need to be taken into considerations for network dimensioning.

2. **The access node.** Because the access node is aggregating traffic from many users, it needs to have enough switching capacity to process all that traffic. This includes the capacity of the connection point, capacity of the internal links between hardware components, and switching capacity of the controller unit (the processor).
3. **The uplink capacity.** The uplink is the connection from the access node to the aggregation or core network. The access node needs to ensure enough uplink capacity from day one and also allow an efficient upgrade path so that more capacity can be added when needed.

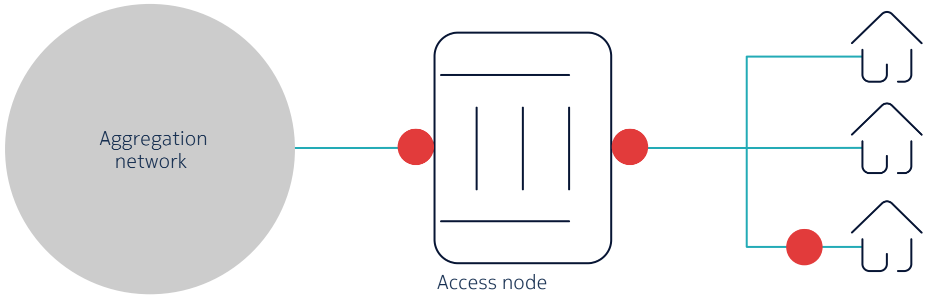


Figure 5. Access network performance sensitivity points

Given the growth in consumer and business demand for high-bandwidth services, network operators need to make their networks future-ready. Investing in high-capacity access nodes will eliminate the need for new investment cycles in the short- or mid-term, and reduce the total cost of ownership (TCO).

2.3 Service delivery models

Broadband services can be deployed in two different ways: a retail service model or an open access/open service model. In a retail services delivery model, one company is both the network operator and service provider. In an open access model, the network provider and service providers are different entities.

The choice of model is based on a number of factors. A retail model is preferred when the infrastructure network provider:

- wants to have a full control of the services delivered
- wants to operate the network and the services
- has staff and experience in running a network and providing services (e.g. municipal utilities).

An open access/open service model is preferred when the infrastructure network provider:

- has no available or experienced staff in operating a network
- does not want to operate the network, and prefers to outsource it
- does not want to compete or is legally bound not to compete against service providers
- wants to have a choice of service providers as tenants.

2.3.1 Retail services delivery model

In a retail services delivery model, one company is both the network operator and service provider. This is the model typically used by incumbent service providers, but it is also used by other service providers (for example utilities) offerings. The network is built specifically to offer their services, not as an infrastructure in itself.

The retail service provider owns the relationship with the subscribers. They define the services to be offered, they promote and deliver them, and bill subscribers, therefore is in direct competition with other service providers in the area.

2.3.2 Open service delivery model

One of the challenges for the infrastructure network provider broadband offering is to make the network appealing to government agencies, financial investors, and other institutions that can bring financing to build the network. One of the ways to do this is to ensure that the network, once built, will be able to attract service providers; to offer attractive services to businesses and consumers; ensure take-up rates; create revenue streams; and make the network financially sustainable. Access nodes can help with this by enabling an open access delivery model.

With an open access approach, multiple parties operate on the same physical network. The infrastructure network provider owns the network assets; a dedicated operator runs it and multiple service providers lease it to provide their services on top. In this way the infrastructure network provider gets a rich set of services and content, and networks become investment-worthy assets.

Implementation of an open access service delivery architecture offers communities, users and utilities several compelling benefits:

- The network supports any type of complementary or competing service providers that offer every imaginable service.
- Multiple service providers can use the same network asset and compete for subscribers.
- There is no operational burden on utility administrators because network maintenance and management activities are carried out by qualified network operators.
- Users are not locked into any particular contract and can freely choose among all service offerings.

As illustrated in Figure 6, multiple service providers will use the connectivity provided by the network operator. The providers could be:

- Internet service providers
- eGovernment service providers
- Business service providers
- Application service providers (e.g., Netflix and Amazon)
- Internet of Things (IoT) service providers (e.g., home security, automation).

Subscribers can choose what they want without being constrained by a single provider's offer. By taking this approach, communities can enjoy best-of-breed services at more competitive prices.

For an open access business model to work, the network architecture needs to enable connectivity that supports a full spectrum of service providers, transparent and impartial delivery of all services, performance level guarantees, and deployment flexibility, at a low TCO. New solutions, like Software Defined Access Networks (SDAN) enable providers to reach these goals more efficiently.

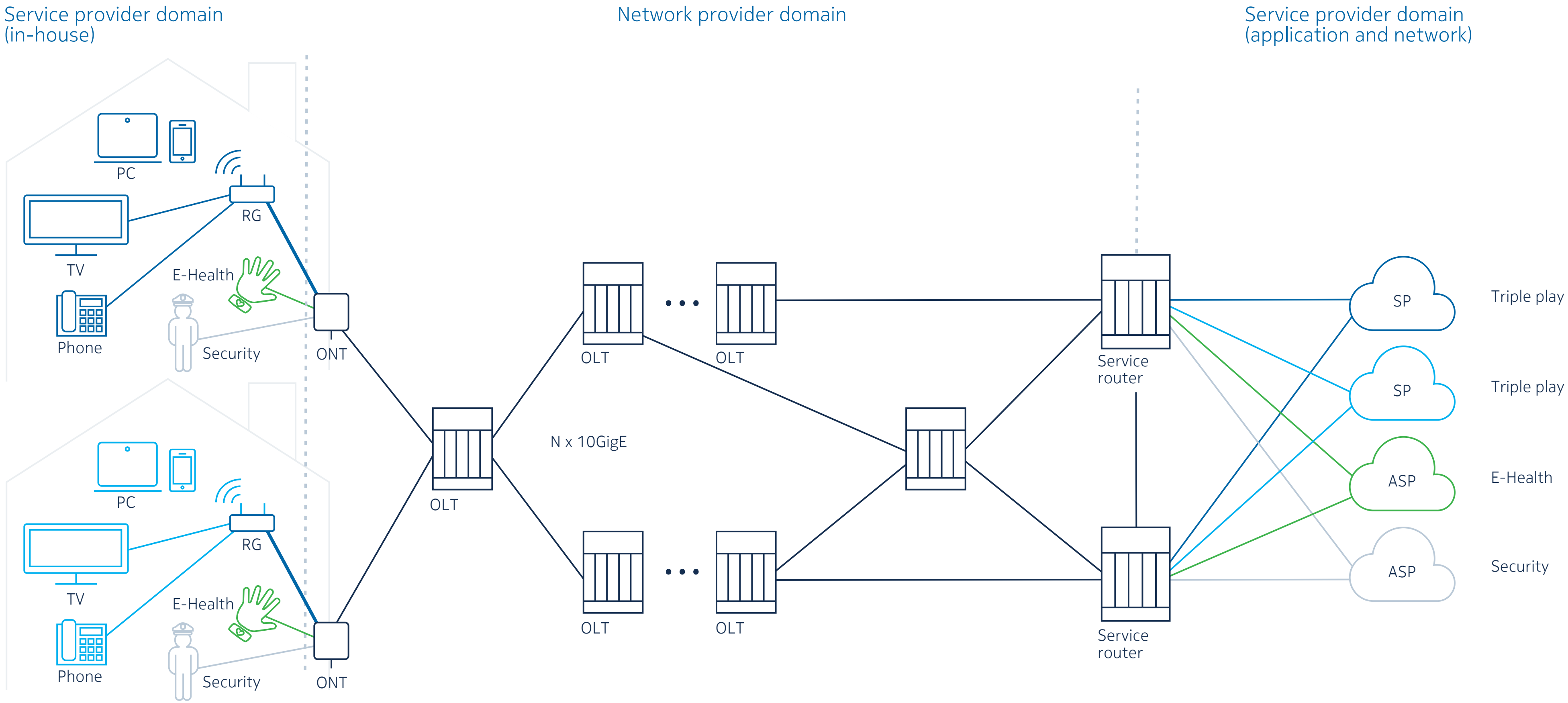


Figure 6. Open access delivery model

2.4 SDAN

SDAN allows operators to virtualize selected access network functions, and run them from the cloud, on general-purpose hardware. This allows them to simplify the operations, gain flexibility and get the network that can be more automated and easily reconfigured on the fly.

- Network Functions Virtualization (NFV) is a concept that virtualizes and centralizes network node functions in the cloud.
- Software Defined Network (SDN) is an approach in network management that provides automated and intelligent control over nodes and other assets in the network.

Defining the network behaviour from the cloud allows operators to access data anywhere in the network and then run algorithms and analytics, resulting in programmable and automated network. It will also bring open interfaces and standards to integrate cross-technology, cross-systems and cross-vendor environments.

Hardware and software disaggregation in independent modules give operators more engineering options to evolve the access network. It allows them to react to changing demands or usage trends, increase network performance, and minimize service impact during software upgrades or equipment replacements.

SDAN introduces many concrete benefits: network slicing, simplified operations, zero-touch activation, troubleshooting etc.

Network slicing is creating a lot of traction, because it opens up the network to new applications or new users. Slicing allows operators to partition their network into multiple slices. Each slice can be assigned to a different “tenant” or “user”. These tenants can be different divisions within a service provider (e.g. residential broadband, enterprise broadband, mobile transport). But they can also be different service providers. Within a slice, each tenant has full control over the network resources assigned (its own slice), giving them a freedom to define the network parameters independently of other tenants.

2.5 Outside plant deployment options

The cost of deploying the infrastructure can be up to 70% of the total network cost, making the decision on deployment technique one of the most important. Continuous innovations in deployment techniques and materials are bringing down deployment costs and creating more possibilities for network providers to choose the most optimal one. It is possible to use more than one technique, depending on the network size, available infrastructure, potential synergies with other projects or existing assets, and other specific circumstances.

As part of the network planning, different right of way access points can be exploited. Deploying aerial cables or putting cables in water, gas or sewage infrastructure can create significant cost savings and improve the business case. It is important to check regulations and laws that will drive this decision and begin the permission process in a timely manner.

If underground cabling is used, a variety of duct infrastructure is available, from large to micro, from flexible to rigid, allowing for different installation tactics and network growth. For example, when aerial cabling is not allowed or reusing existing ducts is not possible, the fiber duct infrastructure needs to be put underground. This can be done either by digging a shallow underground route called micro-trenching (more resistant to damage than aerial cabling but double the cost) or using the deeper full trench method (the most secure, but costing twice as much as micro-trenching).

Aerial cabling uses poles, outside walls and other infrastructure to run the fiber to the end user. This is a far more cost-effective method than putting fibers underground and so significantly reduces deployment costs. Aerial cabling is also fast and easy to install, but it is more sensitive to environmental damage than underground cabling. If aerial cabling is allowed, some factors need to be taken into consideration: existing load capacity of the pole infrastructure, type of cabling, hardware to fix cables on the poles, protection against vandalism, etc.

2.6 Deployment inside residential and business premises

FTTH networks are fueling the gigabit revolution. They open endless possibilities for delivering a premium experience to consumers and businesses for any content on any device. In the home, tablets and smartphones are now commonplace, all connected to the home network and functioning as a seamless addition to TVs and PCs for IPTV or over-the-top video offerings.

A plethora of devices and services combined with demand for gigabit speeds means that the home network has grown more complex and sophisticated over the years. This poses some challenges to users and service providers.

There are two types of equipment deployed inside the home in an FTTH network.

- The **Optical Network Terminal** (ONT) terminates the fiber connection from the outside plant
- The **Residential Gateway** (RGW) provides in-home network connectivity and services support (Wi-Fi, Ethernet and USB connectivity, security, media storage, etc.).

Integration of home networking technologies into the RGW eliminates complexity for the user. And with scalable customer service solutions, service providers can remotely access the RGW to keep the home network up to date and quickly troubleshoot problems when they arise.

The latest generation of RGW includes new wireless technologies like Zigbee and Z-Wave used to connect a wide range of IoT devices.

It is also possible to combine ONT and RGW functionality into a single piece of equipment. The integrated approach brings the advantages of having fewer "boxes", less cabling and a lower TCO. A two-box approach allows the service provider or subscriber to connect their own routers and make upgrades independently of the ONT. Both separate and integrated approaches are seen in the market. The decision to deploy a two-box or an integrated solution depends on the deployment model and future upgrades.

The final connection — from the street to the house, multi-dwelling unit, office block or other building — and the cabling inside the premises can be expensive and linked to many difficulties, such as:

- The willingness of the building owner to give access to installation engineers (due, for example, to the fear of possible damage to the property)
- The availability of building plans
- The need for the subscriber to be present during the installation.

To deploy in-house cabling, the network provider should make a legal agreement with the building owner, including the specification of the ownerships, responsibilities and maintenance issues. This type of agreement will not only make the work of the network providers easier but also help convince the building owner that it is safe to open the building for new infrastructure installations.

An alternative method for user connectivity would be to terminate the fiber connection in the basement of the building and reuse the existing in-house cable infrastructure (the copper lines used for plain old telephony (POTS) voice services). This approach is faster, less expensive, and at the same time still enables high broadband speeds. New advances in technology over the last few years, such as G.fast, enable fiber-like speeds over very short copper cable loops.

3 Network Build-out

Network build-out strategy needs to ensure first-time-right and cost-effective implementation and at the same time provide a solid base for an efficient network evolution. The network build-out is not only about execution and civil works. The successful build-out requires expert project management to ensure the proper sequence of the tasks, engage the right parties, identify the required human resources, and so on.

3.1 Project management

Project management supports the timely and efficient delivery of the end-to-end program and the management of deliverables of multiple parties, including third-party contractors and vendors. An important component is a governance structure to ensure frequent communication and alignment between the multiple parties involved in the program.

Project management should consider the following:

- **Organization planning** identifies the parties involved and describes clear roles, responsibilities and interactions between the project owner, suppliers and other parties
- **Resource planning** needs to include optimal human resources for different project phases and manage “peak and valley” flows and on-the-fly changes

- The **project management plan** includes detailed planning for the workflow, risk mitigation, configuration, change and quality management
- **Program governance** ensures communication between multiple parties, orchestrates parallel tasks, and keeps records and reports
- A **time schedule** records and describes significant program gates and milestones
- A **metrics and key performance indicator** (KPI) framework enables measurement of the performance of service deliverables.

3.2 Outside plant (OSP) and civil works

Rolling out a broadband network is a significant undertaking with extensive civil engineering and construction requirements needed to install the new fiber-optic cables and passive infrastructure and to physically connect each home and building to the new network.

Large-scale OSP fiber-optic backbone and FTTH deployments can be very challenging as they are extremely complex, the cost is considerable, accessing buildings and homes is complicated, skilled labor is difficult to find, competitive time-to-market pressures are great, and there are financial, legal and technical risks.

Experienced third-party companies can help utilities by designing and building the physical infrastructure for the OSP fiber-optic backbone routes and FTTH access networks. Their previous experience and expertise ensure OSP designs are optimized and the deployment projects are implemented seamlessly, according to technical specifications and schedule and budget constraints, by reducing deployment intervals, costs, complexity and risks.

An OSP service would typically provide the following benefits:

- Permitting process for the construction of the plant
- Creation of the passive fiber-optic infrastructure
- Mitigation of the financial risk associated with OSP infrastructure deployment
- Creation of an optimized OSP design from reliable, survey-based OSP models
- Professional, full-scope project execution management by an expert team with a proven track record.

3.3 OSP architecture

A typical PON architecture involves:

- Feeder cable section between the Optical Distribution Frame (ODF) located within the central office and the Fiber Distribution Hub (FDH), including related duct system infrastructure
- Distribution cable section between the FDH, with or without a splitter, to the Fiber Distribution Point (FDP), which is the connection point for drop cables to the subscribers' premises
- FDP at different locations in the Distribution Feeder Network. The appropriate FDP depends on the particular business or residential building being served
- Subscriber drop from the FDP to the subscriber premises or more generally speaking up to the Optical Termination Outlet (OTO) where the ONT will be installed and connected. In the case of multi-dwelling units, the drop network ends at the Building Distribution Box (BDB).

GPON is a very flexible technology that supports a split of up to 1:128 and spans 20-30 km. The PON architecture can vary depending on bandwidth requirements, roll-out plan, take rate, whether it's an overbuild or greenfield application, and cost points for labor and material.

There are two primary PON architectures: the centralized and the cascaded (or distributed) split models.

Figure 7. Centralized split PON architecture

The main advantage of a centralized split architecture is flexibility. The splitter fabric allows patching of the splitter output to any subscriber in the distribution network. A centralized split architecture also provides easier network operations.

A distributed or cascaded architecture is typically used to reduce the amount of fiber needed in the distribution part of the network. However, the labor cost for burying and installing new cable is about the same regardless of the size of the cables. For this reason, a cascaded architecture doesn't provide significant cost savings over a centralized architecture in the distribution network.

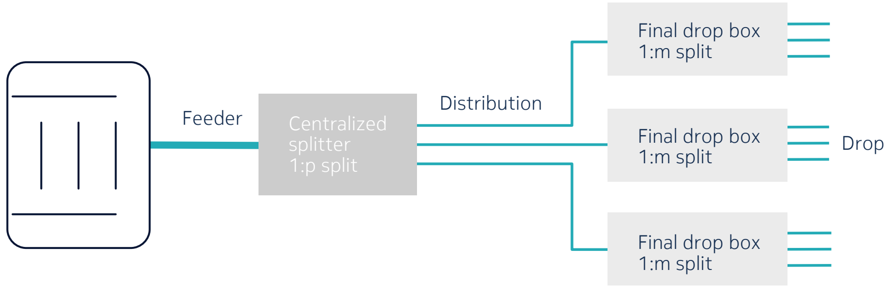


Figure 8. Cascaded or distributed split PON architecture

3.4 Splitting concept

Figure 9 shows the concept of splitting for various different demands per building. The demand per building is determined as part of the engineering and design scope. The objective is to ensure high utilization of equipment ports to optimize costs while accommodating splitters for long-term demand.

For the best balance between flexibility and the number of fibers in the distribution network, splitters can be located in FDH cabinets as well as in large buildings.

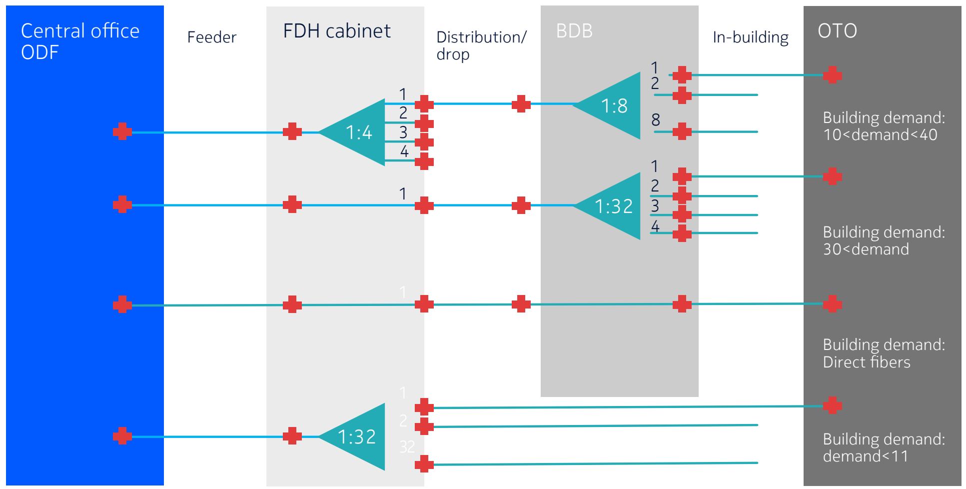


Figure 9. OSP architecture and splitting concept

3.5 Synergies

Digging the streets to lay fiber for the deployment of gigabit services can be a burden for the utility residents and businesses as it impacts reachability of homes, shops and offices and can deteriorate the aesthetic of pavement and street furniture. When a Gigabit project is initiated, there may be an opportunity to coordinate digging and maintenance activities with different utilities such as sewerage, gas and electricity, or work on street infrastructure.

Mid-term and long-term coordination of digging activities can be supported by a central point of coordination, making use of planning tools and geographical information systems (GISs). Even in areas where homes will not be immediately connected to gigabit services, ducts can be laid in conjunction with other digging activities so that fibers can easily be installed at a later stage.

3.6 Documentation

When planning to build an FTTH network, at a certain point in time there will be a need for GIS data about the area: information about the location of demand points (buildings, antennas, etc.) and streets. This GIS data is typically used for creating a to-build plan for the fiber network. All fiber cables, ducts, routes, POP, distribution points, and so on, are documented in a detailed GIS network. All documentation and records collected in the build-out phase need to be consolidated and centralized to support subsequent work in the network (maintenance, repair, future upgrades).

4 Active equipment deployment

Deploying active equipment requires clear delivery methodologies and processes supported by an experienced organization. This includes a pool of program and project managers, central competence and cost-effective delivery organizations for back-office tasks, and local partners for performing the on-site surveys and installation activities.

The deployment of an active network element starts with a site survey and equipment engineering. Then the equipment and site materials are shipped to the site, installed and commissioned. After it is up and running and connected to the network management system, it is fully configured and then tested for proper functioning. After the network element has been tested successfully, it will be accepted and handed over to the network operator.

4.1 Installation and commissioning

A site survey covers the visual inspection of the equipment location, calculation of cable lengths and demarcation points, review of documentation, and collection of other relevant information needed for successful installation. The site survey report is used by the engineering team as input for creating a site-specific installation package, which includes installation tasks, rack/shelf/panel locations, cable running lists, and other data. The survey report is also used to determine and order site-specific installation-related materials (IRM) required for the project. IRM may include racks, mounting hardware, cables, panels, fiber duct, and other items.

A qualified installation crew performs the necessary assembly, cabling and testing tasks. The specific tasks for any given installation are dependent on the equipment being installed, the location and configuration of the site, and other agreements.

Typical tasks may include:

- Install product- and site-specific equipment such as racks, cabinets, shelves, cards, power and ground cables, fibers, fiber panels, fuse panels, and other items
- Perform power-up testing of shelves; verify cable connections and labeling of equipment and cables as per the network owner's requirements and best practices
- Perform equipment installation acceptance
- Commissioning to ensure correct software loads, that equipment is recognized by network management software, and readiness for network integration.

4.2 Integration

Another major challenge lies in ensuring that disparate network elements (for example, OLTs and ONTs for FTTH) work together and also with other outside networks.

Network integration is about integrating "logical groups" of similar network elements into a live network. A logical group requires a level of testing for each and every network element (network element integration) within that group.

Network Integration is done by:

- Planning the logical group of elements
- Preparing an overall test plan
- Repeatedly executing network element integration until the agreed number of individual elements is completed
- Executing the agreed network integration test plan over the logical group of elements (or an agreed subset of the group)
- Getting the network owner's acceptance and sign-off for the logical group of elements.

Network element integration services configure and integrate individual elements into the network and verify that they are fully functional and ready for service.

Network element integration tasks are based on a network owner's needs and can range from a basic set of functional tasks to full integration.

- Basic tasks include confirmation of equipment configuration, connectivity with the aggregation/transport network, passing the proper data to the uplink interface, functionality of the alarm mechanism
- Additional tasks include high-speed link testing, redundancy testing, sync and additional alarm testing, port testing, and configuration of services such as IPTV, SIP, TDM Voice or cable TV.

4.3 Connection to the IP world

Last-mile broadband access networks are only a part of the big picture. When users seek to access content and services remotely over the network, they may need to reach servers and locations in the outside world.

This is provided by interconnections with IP routers in core networks (service provider networks). The key elements of this end-to-end model are the broadband access network, the interconnection between the OLT and IP router, and the internet service provider (IP/MPLS core network).

Figure 10 shows the end-to-end network infrastructure, including the aforementioned elements together with an optical transport network.

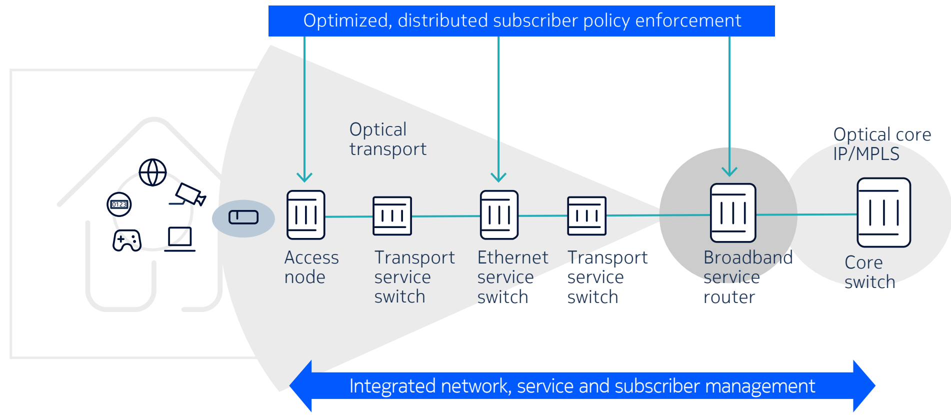


Figure 10. End-to-end architecture for fixed broadband network

5 Network operations

Successfully managing the ups and downs of daily operations is what constitutes the backbone of any business. It is also essential for a utility to manage its broadband network after the network is planned, built and connected to the outside world.

This daily management of network operations ensures:

- Quicker time to market
- Greater return on investment
- Risk avoidance and management
- Quality assurance.

The utility can either handle the network operations activities by themselves or can ask a partner to support their network and all daily activities for an agreed timeframe. The common network operations supported by network providers are provisioning, maintenance and operations assistance.

5.1 Provisioning

Provisioning is the task of preparing and equipping the network to provide new services for customers. It includes the following:

- **Service provisioning** to assign and activate services, implement related (underpinning) service configuration changes, and maintain records to ensure they are kept up to date. Configuration changes include changes to software (e.g., adding new services, changing parameters) and implementing software upgrades
- **Network provisioning** makes network configuration changes and maintains network records to ensure they are kept up to date. Network configuration changes include changes to software (e.g., adding new routes, changing parameters) and implementing software upgrades
- **Subscriber management** manages end-user (subscriber) interactions, including the helpdesk, records maintenance, and billing.

5.2 Maintenance

Preventative and reactive maintenance are critical considerations for operating a network in order to maximize network uptime and quality of service. The utility can either handle this themselves or can ask a partner (like Nokia) to support their maintenance activities.

Following are three typical maintenance services:

- **Technical support** provides remote access to experienced engineers for product-related questions, troubleshooting assistance, diagnostic procedures, and software fixes to quickly restore and resolve network problems
- **Repair and exchange** services provide repair or replacement of defective equipment and parts. If network components come from different equipment vendors, each may offer repair and exchange services. Some vendors and independent maintenance companies can support equipment from multiple vendors, simplifying the logistics and maintenance spares inventory
- **Field maintenance** services provide access to experienced on-site technicians to perform faulty equipment replacement or other directed maintenance activities to restore and maintain optimal equipment operation.

5.3 Operations assistance

Operations assistance can be provided to support and train a network operator's staff. This is especially important in utility broadband networks where experienced resources may be limited but is also applicable for established service providers.

There are two primary stages:

1. **Operations assistance.** Supplying operations subject matter experts to support and train surveillance, fault management, and network performance management teams using their own facilities, tools, platforms, and processes as well as providing operations benchmarking services
2. **Transition back to the customer.** Developing and executing a transition plan for migrating the technology knowledge, processes, methodologies, and activities. A transition plan should be designed and executed to mitigate risks in the operational management of the new network.

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