Regardless of the upgrade path selected, the same three criteria apply when selecting the optimal network components that will create the new infrastructure - upgradeability, capital spending (CapEx) and operational spending (OpEx).

I still remember the first time I connected my PC to the Internet and started surfing the web - it was an incredible experience. Looking back, the connection was a dial-up and was fraught with busy signals and dropped calls. But I felt empowered, now able to communicate freely throughout the world. And that was no less exciting than the day a cable operator deployed coax to my apartment. The house was flooded with dozens of new TV channels and I now had a permanent “always on” Internet connection with a whopping 3Mbps of bandwidth. For the first time, I felt I was going to truly start enjoying the Internet.

That was back in the 1990s, when MSOs embarked upon an exciting race to challenge the status quo of incumbent and telcos operators across oceans, boosting innovation in the telecommunications sector and ultimately fueling Fibre-To-The-Home (FTTH) deployments all over the world.

Cable operators have come a long way since 1980, when they first upgraded their coax cable networks to Hybrid Fibre Coaxial (HFC) architecture. This design, in combination with Data Over System Interface Specification (DOCSIS), has given cable operators ample capacity to deliver triple play services – voice, high bandwidth and a wide TV channel offering.

Today, cable operators have more paths than ever to Gigabit broadband to remain ahead of telcos, municipalities and other ISPs who are pushing fibre deeper. The decision on which upgrade path to choose depends upon strategic factors (competition, capacity demand, demographics etc.) but, regardless of the technology of choice, choosing the optimal network components – from headends to distribution boxes – can have an important impact on network upgradeability and total cost of ownership.

Towards the Gigabit network
Cable operators have several short- and long-term upgrade options to keep pace with growing capacity demand.

In brownfield deployments, where bandwidth competition is low, cable operators are relying on techniques (node segmentation, recovering capacity from deleted analogue channels, channel bonding or MPEG-4 video compression) that optimise the use of bandwidth so they can continue working over their current HFC infrastructure. Running on these networks, DOCSIS 3.0 technology can deliver speeds up to 1.6Gbps downstream and 160Mbps upstream, enough to cover requirements for current asymmetric broadband services. In areas where higher bandwidth is required, the more recent DOCSIS 3.1 technology enables further capacity upgrades with speeds of up to 10Gbps downstream and 1Gbps upstream, enough to guarantee future provisioning of Gigabit services.

When the capital to upgrade the network is limited but competition is fierce (or there is only one segment within a particular area strongly demanding higher capacity), many cable operators opt to deploy a technology called Radio Frequency over Glass (RFoG). RFoG technology allows cable operators to provide traditional HFC/DOCSIS-based services using DOCSIS hardware over a standard Passive Optical Network (PON) while reducing the initial level of investment in headend equipment. RFoG delivers the same services as an RF/DOCSIS/HFC network, with the added benefit of improved noise performance and increased usable RF spectrum on to the downstream and return path directions.

Both RFoG and HFC systems can concurrently operate out of the same headends/hub, making RFoG a good solution for splitting nodes and capacity increases on an existing network. However, although RFoG provides some of the benefits of FTTH, it still requires the infrastructure investments of a traditional HFC/DOCSIS system. An RFoG deployment requires additional transmitters in the headend for capacity, additional ports on the CMTS and, in many cases, requires the deployment of new nodes into the field. Once these investments are completed, the deployment costs could be considered on par with a traditional GPON/GE-PON deployment. Longer term investments, such as a mid-split, are still required to increase the upstream bandwidth more.

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towards symmetry with the downstream, and operational costs supporting the new node and transmitter infrastructure are far greater than traditional PON technologies.

In high-density areas where greenfield builds are required, FTTH technology is the preferred choice for cable operators. PON technologies can offer more services over the same infrastructure with less hardware, lower complexity of management and lower operational costs than traditional HFC. PON solutions have the added benefit of creating scalability for bandwidth demand and offer enhanced upstream capacity with ultra-high-speed services: GPON can offer 2.5Gbps download speeds, 1G EPON can deliver symmetrical 10Gbps and TWDM PON technology can even deliver 40Gbps. For longevity and capacity considerations, fibre provides both long-term service and revenue potential.

Among these upgrade options, the correct choice depends upon numerous factors that must be carefully analysed by the cable operator. Regardless of the upgrade path selected, the same three criteria apply when selecting the optimal network architecture.

**Building the optimal network**

Whether the underlying technology is HFC, RFoG or xPON, the ultimate goal for any operator is to deploy an infrastructure that scores high on upgradeability and as low as possible in capital and operational expenses. Upgradeability of cable and hardware equipment will guarantee a fast transition to RFoG, xPON and any FTTH technology.

Easy-to-install equipment for rapid roll-outs and a “pay-as-you-go” approach to reduce initial construction costs will ensure low CapEx. Robust components to minimize truck rolls and simplified inventory with network components that can be re-utilised in different parts of the network can make a massive difference in terms of OpEx.

These three aspects have to be carefully considered when choosing the optimal network architecture.

**Headend equipment**

In fibre-rich application spaces, such as headends, high-density fibre management systems with optimised cable and patch cord management are highly recommended.

Increased port density and smart cable management in the headend allow a high degree of flexibility for new and subsequent re-configurations, as well as for future capacity upgrades. A headend should also be able to meet the requirements of multiple applications while also offering flexibility, simplicity and high density.

Superior jumper management and simple fibre routing are critical, while optimised routing paths for cables and jumpers can reduce the risk of pile-up or entanglement, saving on maintenance costs.

**Micro cables**

Designed for installation in microduct systems using air-assisted installation methods, micro cables offer increased fibre density when compared to standard loose tube cables in a small cable diameter footprint. This cable technology is becoming more and more popular for its “pay-as-you-go” approach, its capacity to re-utilise blocked or congested ducts and for enabling new deployment techniques such as micro trenching that can reduce civil costs by 70 per cent. Micro cable technology also scores very highly on installation speed and upgradeability of fibre cable infrastructure.

More recent versions of these cables eliminate the use of binders, water blocking yarns and tapes for much faster mid-span access and reduced the risk of buffer tube damage. A flame-retardant design enables seamless transition from the headend to the outside plant, eliminating the need for expensive transition points.

**Local convergence cabinets**

Outdoor street cabinets should include pre-stubbed feeder and distribution cables and modular field-installable cassette platforms with onboard splicing. Modularity is the best tool for rapid customer configuration and to enable “grow-as-needed” connectivity - modular cabinets can save up to 75 per cent compared to fully configured alternatives.

Intuitive fibre routing, with no need for access tools, is also important in field terminations and re-configurations so a highly skilled labour force is not required. With a modular approach, if cabinets and headend equipment come from the same manufacturer, the same cassettes could be used for both network elements, simplifying construction and reducing training and inventory complexity.

**Distribution network**

The purpose of the distribution network is to provide a deep spread of network connectivity points so that customers can be easily connected as service is requested. This is a labour-intensive and costly process, and pre-connectorised solutions have been widely proved to offer significant speed and cost savings in this part of the network.

One of the key challenges, particularly in a situation where competitive operators are in a race to deploy NGA (Next Generation Architecture) infrastructure in the same territory, is the time to deploy. This can often be constrained by the availability of skilled labour. In these cases, pre-connectorised systems are best suited to ensure rapid provisioning with fewer installation teams, shortening time to revenue and minimising network disruption. With fully pre-connectorised systems, homes can be passed three to four times faster compared to traditional spliced solutions.

Hardened connectorised products can increase capital deferment opportunities, so connection ports and splitters only need to be added as needed. When a splice point is required to branch large distribution optical cables into lower-fibre-count cables, in-line closures can ease incremental connection of subscriber drop cables while increasing deployment velocity. Optical splitters can also be housed inside these terminals, which is particularly appropriate for distributed split PON architectures.

**Drop network**

The customer drop portion of the network may seem like a simple last step but, in fact, has the highest degree of complexity of all parts of the network. For example, drop cables must be suitable for a wide range of installation environments such as aerial, duct, façade or direct buried, but must also be suitable for installation inside the personal space of the customer’s living room. This requires novel drop cable designs with fast access features and multi-purpose capability.

It is in the drop where the use of pre-connectorised solutions can provide the biggest benefit. Here, it is most important to reduce the time, cost and skill level of the installers. The aim is to achieve a fibre installation process which is similar in speed and complexity to a coax CATV installation, and a combination of hardened and field-installable connectors has made this possible. These products have been shown to enable a doubling of the productivity of operators’ customer connection resource compared to conventional spliced solutions.
MDUs
As part of a cable network transformation, distribution boxes are needed at the basement and often floor level. The floor box (if required) can be a very interesting element of the network for a cable operator, as ideally it should be capable of handling any signal conversion (electrical to optical and vice versa) or simply distribute RFoG over coax or iPON solutions over fibre.

Modular housings with blades or cards, that are easy to configure and add when increasing capacity, are best suited for this job. Modularity reduces the impact of failure and protects work areas, but most importantly, it ensures that the housing is versatile enough to allow technology upgrades by simply replacing the blades. Optimised coax and fibre cable routing is again essential, as well as the flexibility to add splitters, splicing boxes and patching applications.

On top of the variety of upgrade tools from which a cable operator can choose to deliver high-capacity networks, there is a wide variety of equipment that can make up each design. Each MSO is unique and it would be naïve to pretend that one solution satisfies them all.

Conclusion
A lot has happened since 1980, when MSOs began the transition to hybrid fibre coaxial HFC systems. The MSO industry has continued introducing new, higher capacity technologies to keep up with the relentless demand for consumer bandwidth and, thanks to that continued innovation, cable operators today have a larger toolkit that they can use to upgrade their networks and remain competitive in the Gigabit era.

The technology they choose will depend upon their business model and strategy. Once that decision is made, the next critical decision is selecting the right partner to help design a network that can reduce deployment and maintenance costs, while ensuring a seamless transition to the network of the future, today.

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