Universal Gigabit Optical Access (Invited Paper)

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Abstract: We review the imperatives on the optical communication technology industry to realize universal ultra high speed access to the world's information.
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1. Introduction

In 1970, twenty years before Tim Berners-Lee first proposed the World Wide Web, Arthur C. Clarke predicted the existence of a console that would "bring the accumulated knowledge of the world to your fingertips" [1].

In 2010 the 'console' is a PC, Tablet or Mobile device and the Web turned twenty years old, during this period the Web has become the primary repository for many forms of knowledge. The next two decades will see both traditional forms of media migrate fully to the Web and emerging forms of Web based social interaction become even more integrated in to the fabric of human life.

In this invited paper, we highlight some technology trends and imperatives facing the optical communication technology industry which must be addressesed if devices attached to Fiber to the Home (FTTH) Networks are to realiaze the potential of Arthur C. Clarke's vision, enabled by universal gigabit optical access.

2. Dedicated fibers

Point to multi-point passive optical networks (PONs) are often assumed the technology of choice for incumbent carriers to deploy FTTH Networks [2,3]. There are several economic drivers which on the surface appear to warrant such an assumption two of which are, a) PONs enable certain capital costs to be shared across many more users, for example through fiber sharing in parts of the access network, and b) PONs enable a smaller equipment footprint at a Central Office location then would be required for point to point networks.

However, building a fiber access infrastructure is capital intensive and it is therefore important to 'future proof' any such deployment. A network constructed as point to multi-point is by definition not future proof. For example, if any one user served by the network requires more capacity then is available on the shared PON then the only option is to disconnect the user from the shared PON and reconfigure the access network to serve that user with a dedicated fiber or additional wavelength. It is therefore an imperative that FTTH Operators where possible deploy dedicated fibers to each user. It should be noted that this does not preclude the possibility of using PON type network technology, since whether an outside plant network is point to multipoint is merely a design parameter related to optical or wavelength splitter placement.

Additionally, the privacy and security of users is becoming an increasingly important issue on the Web. Whilst all network links in long-haul and metropolitan networks are shared resources, the reader may wonder why this is a specifically an issue in FTTH Networks. The key difference is that FTTH Networks bring bits directly in to user's homes, and therefore even the perception of any vulnerability to snooping could harm market adoption. In point to multi-point networks any bits sent downstream from the network are visible to all users connected to the network, whereas this is not the case if dedicated fibers are used.

3. Gigabit symmetric access

Low cost generic networking equipment is prevalent both throughout the enterprise IT world, and within the switching fabrics of datacenters. Today 1 Gbps Ethernet switches with up to 48 ports are essentially a commodity component [4]. Commoditization of networking hardware has been one of the necessities for the development of warehouse scale computers [4].

The state of optical access networks in many ways is analogous to the development of personal computers through the late 1980's, where the development of IBM Compatible PC's running Windows for the enterprise eventually triggered an explosion in the growth of home computing. Another computing revolution based on low cost ubiquitous gigabit access to the Web may be enabled by generic access equipment based on high volume technologies (like Gigabit Ethernet). Leveraging such high volume technologies may be preferable over implementing more specific implementations, for example one of the several varieties of PON technology [2,3].

We believe another imperative for the optical communications technology industry is the requirement for 1 Gbps symmetric access. Bandwidth asymmetry is usually a characteristic of both the underlying transmission technology whether copper, fiber or coaxial, and the user behavior associated with accessing information from the Web, for example one speaks of 'downloading' large files. Symmetric gigabit access will enable new forms of Web content caching, potentially enabling a greater proportion of content serving from distributed caching systems.

4. Ascendency of wireless devices

Mobile wireless devices are likely to be the primary method of accessing Web and social networking applications during the next evolution of consumer technology. These devices, whilst in their own right quite capable of powerful computations, often harness the very large scale computational capability of servers located in datacenters to provide useful and compelling services to end users. A typical datacenter contains thousands of identical servers arranged into one or more clusters capable of performing large scale computations [3] such as required by machine translation or image search applications.

Ultra high speed access to this warehouse scale computational infrastructure is thus critical to mobile wireless devices but radio spectrum is a scarce (and therefore expensive) resource. It is in offloading traffic from wireless devices that optical networking can play a large part. In principle, provided enough bandwidth was available not to affect the primary user of the FTTH Network, any mobile device within range of a FTTH Network optical network terminal (ONT) should be able to route data over the Fiber network. Doing so would leave the RF Spectrum available to actual 'mobile' devices, that is to say devices which are 'moving'.

5. In service self diagnosis

Whereas the large capital costs of FTTH Network construction can be amortized or depreciated over many years, operational costs are expensed against the operating entities bottom line and ongoing. Reduction of such expenses is thus crucial to an organizations business case in deploying new optical access networks. One principle component of operating expenses is maintaining the optical plant and locating fiber breaks, bad splices or connectors with poor performance.

An area that is ripe for development is integrated fault location and in service diagnosis of FTTH Networks. Whereas approaches to perform in-service PON optical time division reflectometry (OTDR) exist in the public domain, consisting of in general, a wavelength selected from the 'U-band' between 1610nm and 1650nm for OTDR, that wavelength then being injected into the fiber plant through a wavelength division multiplexer, the OTDR wavelength being blocked or reflected at the remote end of the fiber plant to prevent interference at the receiver with wavelengths carrying live traffic.

However there is no cost effective in-service online OTDR system yet available on the market suitable for use with dedicated fiber access systems. Thus a further imperative for the optical technology industry is to develop a cost effective integrated solution for in service diagnosis of FTTH Networks. Such a solution would constantly monitor the entire access network and automatically locate faults across many thousands of fibers, bringing the exact location of the fault to the attention of an operator or an automated dispatch system.

6. High density and low power consumption

In many FTTH Network deployments a typical 'Central Office' serves between 10,000 and 30,000 users, terminating this many optical fibers in a dedicated fiber architecture is a challenging task. For example not considering sparing, some thirty five 864 fiber ribbon cables would need to be terminated, cross connected and patched to serve a 30,000 home FTTH Network. The currently available state of the art fiber patch panel can terminate just over six thousand fibers in a standard 7-foot telecoms equipment rack. [5] Thus even at the maximum theoretical density five full equipment racks are needed just for fiber termination, practical issues surround routing fiber patch cords may increase this space requirement by a factor or two or three.

Additionally state-of-the art commercial equipment supports around twenty six hundred 1 Gbps ports per standard 7-foot telecoms equipment rack [5]. However, practical limits on air conditioning systems mean that at a power consumption of 2.5 Watts per port a limit of twelve hundred 1Gbps interfaces per rack is encountered. [5] Thus at such a density a total of twenty five racks are required to serve a 30,000 home FTTH Network.

Higher densities for both fiber termination and optical equipment, and lower power consumption are imperative to lower the capital and operational cost of gigabit symmetric access through reduced power and space requirements. A

FTTH Network 'Central Office' could then be constructed in a modular fashion utilizing production line methodology and be operated without the need for active cooling apparatus.

7. Google Fiber for Communities

In February 2010 Google Inc. announced an experimental Fiber to the Home project [6]. As well as announcing a plan to deploy 1 Gbps FTTH Networks to between 50,000 and 500,000 people, Google issued a request for information (RFI) to elicit responses from US communities interested in becoming the test location for the experimental fiber deployment. More than 1100 US Cities, Counties and Municipalities representing over one third of the US Population responded to this RFI [Fig 1]. Google hopes that the experimental Fiber network will serve as a proving ground for some of the approaches to providing universal gigabit access outlined in this paper and an exploratory test bed for potential alternative FTTH build models. [7]

Figure 1 - This map displays where Google Fiber RFI responses were concentrated. Each small dot represents a local government response, and each large dot represents a location where more than 1,000 residents submitted a nomination

8. Conclusion

To conclude, gigabit access to the web must become the new standard for which both operators and communities strive toward to maintain economic growth and to improve the quality of life of citizens, broadband infrastructure is key to realising the potential of the Web as the repository for the accumulated knowledge of the world, and universal gigabit optical access is the apogee of this progession. We believe gigabit access should become the defacto standard for FTTH Networks and this must be enabled by the optical communication technology industry.

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