Fibre to the Home: A CWIRP Background Paper

Matthew Wong
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Introduction

With the current trend towards high-bandwidth digital services such as the Internet and High Definition television, network operators, service providers, and governments are increasingly turning to Optical Fibre technology to support this demand. In this background paper I will begin by briefly describing Fibre to the Home (FTTH) and the various forms of fibre networking applications and architectures. Following this overview, I will then discuss the issues related to fibre deployment and implications for future fibre roll-outs.

What is optical fibre?

Optical fibre is a glass or plastic filament designed to guide light along its length. With the traditional copper wiring used in telephones and television cables, electrical signals are passed along the wire. With fibre, a light-emitting diode or laser diode is used to pulse light at one end of the fibre, which then travels (at the speed of light) along the length of the fibre using a principle known as *total internal reflection*. The received light pulses are then translated into electrical signals using photoelectric sensor units. Glass fibre had been used to displace copper wiring since the late 70's (Shumate, 1989).

Mayhew, Page, Walker, and Fisher (2002) summarize a number of key advantages of fibre cables over traditional copper wiring:

1. much higher bandwidth capability (compare several Gbps transfer versus approximately 8 Mbps download and 640 Kbps upload with ADSL)
2. can transmit data over long distances with comparatively less signal loss
3. smaller (in diameter) and lighter than copper, which affects their installation, handling, and transportation
4. unlike copper wiring, fibre does not corrode and can withstand long periods of water immersion without failure
5. optical fibre transmission is immune to interference from signals carried on other fibres or metallic transmission paths within the same or adjacent cables
6. optical signals are not affected by radio frequency emissions or generate any themselves (pg.92)

In comparison, the same authors cite that the two main disadvantages of fibre optics are the difficulty of joining together and terminating fibre filaments, necessitating more skilled labour and more expensive tools, and the generally greater cost per cabled fibre compared to cabled copper pair[1] (Mayhew, Page, Walker & Fisher, 2002, pg. 93). However, the greater cost of cabling may be mitigated by the fact that greater numbers of customers can be served with less fibre cabling than copper wiring.

[1] Telephone lines use a twisted-pair of copper wires, whereas cable television uses co-axial copper cabling.

How is fibre used?

Generally speaking, fibre is used as the conduit for "core" network operations for telecommunications and network service companies, government facilities, academic institutions, and other organizations requiring or selling high-capacity bandwidth. Fibre is used to link exchanges or data centres together with high-speed transfer. For example, the Canadian Advanced Networks and Research for Industry and Education (CANARIE) network, *CAnet 4*, uses OC-192 (Optical Carrier level 192, approximately 10 Gbps) optical networks to link provincial research networks throughout the country.[4] Branching out from exchanges like these are "access" networks where connections are used for comparatively smaller applications like offices and neighbourhoods. In Canada, Rogers Communications Inc. offers fibre services to businesses[5] and Bell Canada offers their "Optimax" fibre services to both businesses and home consumers.[6] The local exchange may provide this access using traditional copper wiring (i.e. telephone based DSL or cable based services). For television this may go into a set-top receiver box and for Internet, to a cable or DSL modem which then connects via Ethernet cabling to a computer. The combination on fibre and copper is known as a hybrid line.

This general description gives way to a variety of different, more specific, fibre optic network architectures. These may be applied in a variety of different ways in addition to FTTH. There is also Fibre to the Premises (FTTP), Fibre to the Curb (or kerb in British English, FTTC/K), and Fibre to the Node (FTTN). All of these types of applications refer to the level at which the fibre terminates and copper wiring may or may not take over. Koonen (2006) described the different kind of fibre architectures as (1) point to point, (2) active star, and (3) passive star[7]. Point to point means a fibre connection directly from the local exchange to the termination point, in the case of FTTH, directly to the home. This results in the maximum amount of bandwidth available to the consumer at a cost of higher service fees, and the requirement of as many fibre terminals as customers. Active star architecture uses a single fibre to carry all traffic to an "active node" which is located close to the end users, then individual fibres take over to additional nodes in homes or street-level cabinets. The active node takes care of the switching and transmission. In a passive star architecture, the active node of the active star is replaced with a passive power splitter/combiner that then feeds the branching fibres. This is also known as a Passive Optical Network (PON). However, this means that the receiving device in the home needs to be more complex to perform operations similar to what the active node would have done. In industry terms, this home device is referred to as Customer Premises Equipment (CPE).

Issues in Fibre Deployment

In terms of fibre deployment to customers, there are generally two kinds of scenario. The first is what is known as a "green field" situation where there is a new development with little to no existing copper infrastructure. For example, according to Kettler, Kafka, and Spears (2000) in the south-eastern United States prior to 1995, Bell South had deployed copper cables as the infrastructure of choice for new developments. However, after 1995, Bell South decided that FTTC "had reached the point where its life cycle cost was lower than that of copper for new

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[4] See http://www.canarie.ca/advnet/index.html
[5] See http://www.shoprogers.com/business/data/TLS.asp
[6] See http://www.bell.ca/enterprise/EntNews_newsLetter_Sep2006_8.page (consumer services) and http://www.bell.ca/shop/Sme.Sol.Internet.Optimax.page (business services). Consumer services use FTTC and then switch to conventional copper lines, although of higher capacity than standard DSL.
[7] See this reference for helpful diagrams of these architectures. See also Frigo, Iannone, and Reichmann (2004) for additional diagrams.

builds, and FTTC became the preferred architecture" (Kettler, Kafka & Spears, 2000, pg.108). As a result, by the beginning of 1999, over 200,000 lines of FTTC had been installed in new builds. More recent numbers indicate that Bell South has deployed FTTC to 1.3+ million customers with Verizon deploying FTTP (homes, multi-dwelling units, businesses) to over 3.6 million homes with an estimated 500,000 subscribers (Wagner et al., 2006).

The other scenario is the replacement or rehabilitation of existing copper lines. As copper cables deteriorate with age, some after decades of use, it becomes necessary to replace them. Often, the process of installing new fibre in place of copper is expensive, not just because it involves digging up and exposing the ductwork which holds the copper, but because new fibre then needs to be rolled out in its place. As one Bell Canada report indicates when considering deploying a hybrid fibre/copper connection, "the operational savings do not fully offset the high costs of electronics, service migration costs and potentially negative customer impacts, thus limiting this option to areas of severely degraded copper plant" (Di Michele & Huppe, 2006). In other words, introducing fibre where the copper connections are still in operational condition is too expensive and should only be pursued when the copper lines are in dire need of repair or replacement anyway. As an alternative, however, areas can also be served by using aerial deployment (e.g. telephone poles). Using aerials usually means less ductwork would need to be exposed, reducing the amount of damage and construction that would be required.

Another key issue in fibre deployment is one related to the costs of deployment: determining an appropriate business model for deploying it to the consumer. While demand for bandwidth for Internet connectivity and high definition television are on the rise, some remain sceptical about the need for such high bandwidth capacity as fibre running directly to consumers' homes. For example, Tompkins et al. (2000) wrote that "to assume we will need this bandwidth running into our backyards is another issue…the demand for bandwidth is generated by the services and applications that can be provided by service providers" (pg.112). They add that in addition to the high initial cost of deploying fibre all the way to the home, the CPE is usually more expensive as well (Tompkins et al., 2000, pg. 121). Frigo, Iannone, and Reichmann (2004) also introduce a different perspective on the capabilities of fibre. In their paper they discuss the importance of the *perception* of bandwidth. For example, in activities like surfing which require bandwidth in bursts for downloading a page, followed by a period of viewing that page, a consistent, high-capacity bandwidth may not be necessary. They note that

> consumers are expected to be concerned more about the services and their cost than about the technology that delivers them…as a result, the tremendous bit rate potential of FTTH is mostly unused when applied to the services consumers pay for today…this begs the question of whether newer non-Web services such as peer-to-peer large file transfers and streaming applications on conventional media will become a driver for a replacement technology (S18).

As one example, consider that Bell Canada's Total Internet Max/Optimax service utilizes FTTN and then VDSL2 lines to the home, which provide speeds of up to 16 Mbps. However, as of November 2007, this costs $100/month compared to their 7 Mbps regular service at $50/month. Perhaps it is an important question as to whether customers will perceive enough difference to pay twice as much. To note one last difference between fibre and copper services, fibre will not operate in a power failure like standard copper phone lines would. In the case of an outage, backup power would be required to maintain a telephone connection.

FTTH Going Into the Future

Despite some of the noted issues about how and where to deploy fibre, it seems indisputable that fibre will continue to be deployed. Wagner et al. (2006) predicts that we can expect "100 [Mbps] service projected by this data to have a few million subscribers by 2010, and another higher service offering of GbE [Gigabit Ethernet] projected to be penetrating the customer base by 2016" (pg.4527). While there might be some issues with finding suitable applications to take advantage of such high bandwidth, it also seems likely that eventually those applications will exist, whether they are Internet-based or through high definition streaming video or perhaps some as of yet undeveloped technology. Consider that Shumate (1989) noted that fibre was envisioned for "conventional video and high-definition television, and for still-frame displays for information retrieval or catalog shopping" (pg.46). Perhaps we may not even know what applications are in the near future, but it is likely to expect that they will need more bandwidth than we presently use, not less. Finally, Tompkins et al. (2000) speculate that

> FTTH/B [building] is likely to be more successful when the decision comes down to more than just economics. For municipalities, there is a sense of future proofing the network for the good of the community - putting in the best possible network because their community wants it and the services it can provide. Not to say that economics is not a factor, but it may be less of a factor when the town allows the utility or itself to amortize the equipment over 10 years and the fibre over 20 years. Playing with those numbers at $50 per month can easily justify a FTTH/B network with room to spare. (121)

Indeed, in this way, despite what might kinds of applications might be developed, FTTH can ensure their accommodation in the future.

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