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Broadband Optical Access Networks

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Abstract

This talk will provide a perspective on broadband optical access network trends, and discuss the next-generation fiber-based and optical wireless systems for the access infrastructure needed to meet future demand for high-bandwidth information services

Summary

Over the past five years, telecommunication networks have experienced a dramatic shift from traditional voice-dominated traffic to data-oriented, application-driven traffic. Driven by the exploding growth of Internet users, data traffic consists of 50% of all traffic today and may soar to about 90% in 2004. To meet the demand, telecom service providers spent most of the efforts and resources to boost up the bandwidth in network backbones through massive deployment of DWDM technologies. However, the access infrastructure has not been upgraded accordingly to allow high-speed access to the core networks. As a result, only 2-3% of bandwidth is utilized in today's core networks while the end users, residential or business, are still in clear and great need for more bandwidth. We believe that the next trend of growth in the worldwide network market will be in the broadband access arena.

Optical broadband access technologies [1], providing high-speed optical connections to the end users, will play an essential role in alleviating the last mile bottleneck for next generation access networks. With the cost-reduction in optoelectronic technologies for the past few years, it becomes apparent that optics will move deeper and deeper into the networks to provide the much-needed bandwidth. Compared to the traditional connections via copper, optical systems can certainly offer at least 10 to 100 times more bandwidth over a much larger coverage area, hence having the potential to sign up a sufficient number of customers to support the upgrade efforts. The point-to-multi-point topology further enables flexible deployment toward reaching a large number of end points. In our view, three optical technologies will be the most promising candidates for both enterprise and residential broadband access applications: active point-to-point or active star networks, passive optical networks (PON), and optical wireless (free-space optics).

Active Point-to-Point Links or Active Star

In active point-to-point links, each subscriber is connected to the central office (CO) via a direct fiber link and the optical signal is terminated at the optical network unit (ONU) at the subscriber side. The CO is responsible for all data switching functions. However, this type of network is too expensive in terms of dedicated fibers. An alternative is the active star configuration which employs a feeder fiber to carry the multiplexed signals from the CO to a distant remote node (RN). The RN terminates and electronically demultiplexes the signals from the feeder fiber and then distributes the signals to the subscribers over fiber. This can save much fibers, as compared with the point-to-point links, but the RN requires electrical power for the demultiplexing electronics and optoelectronic components.

Passive Optical Networks

Passive optical networks (PONs) refer to a passive optical system with active optoelectronics only at the network's endpoints (CO and subscriber premises (ONUs)). A high-bandwidth optical signal is sent from the CO on a single optical fiber and then optically split using a passive optical splitter to multiple ONUs. The network architecture can be star, bus, ring or tree. Currently, there are two different approaches in PONs development, namely ATM-PONs (APONs) and Ethernet-PONs (EPONs). Both of them employ time-division multiple access (TDMA) to share the bandwidth among subscribers in both downstream (at 1550nm) and upstream (at 1310nm) directions. The difference between APONs and EPONs is that the former carries ATM traffic while the latter is Ethernet-centric. APONs can offer quality-of-service (QoS) control and customer's service level agreement (SLA) but require expensive ATM equipment. Nevertheless, EPONs, though may not be able to offer QoS and SLA, has relatively lower equipment cost and a larger installed base in enterprise networks where Ethernet is the dominant protocol. In view of the ever-increasing bandwidth demand of subscribers, PONs may evolve to use wavelength division multiplexing (WDM) technology to provide dedicate bandwidth to each subscriber.

Optical Wireless (Free-Space Optics) Technology

Optical wireless technology can be a complementary solution to the fiber-based access networks. The principle of optical wireless technology is to use laser beams to transmit high-speed (mega/gigabit per second) data via point-to-point or mesh topologies through the air[2]. This is an attractive candidate to provide last-mile connections (up to 5 km) where the buildings are close to the fiber-optic infrastructure but not directly connected with fibers. The transmitting and receiving unit is a telescope with an incorporated optical transceiver, thus allowing bi-directional transmission. Most vendors employ laser beams at 780-920nm range to achieve lower cost while some others use 1550-nm lasers to achieve better eye-safe operation. No FCC license is required for transmission at such optical frequencies. As a line-of-sight technology, optical wireless systems are vulnerable to several environmental factors, including bad weather, poor atmospheric visibility, building sway, scintillation, etc. However, these can be resolved by systems with built-in intelligence such as automatic tracking and alignment, etc. To obtain even better reliability, unlicensed frequency radio systems can be used to backup the optical wireless systems when the weather condition is poor.

Future Prospects

It has been estimated that only a very small percentage of buildings today are connected with fiber . However, a large portion of the remaining buildings that do not have fiber connections are located within 1 mile to the nearest fiber presence. A hybrid system, combining the best of fiber access networks and high-speed optical wireless solutions, may address the immediate issue of fiber availability by providing instant bandwidth to the end users.

Fiber-to-the-home (FTTH)[3] is definitely the ultimate solution for the access networks. However, component and deployment cost will determine the timing of a full-scale acceptance of the technology. Before FTTH becomes a reality, there are several intermediate solutions to provide cost-effective methods to deliver high-bandwidth access to subscribers. For example, fiber-to-the-MDU (multi-dwelling-unit) / MTU (multi-tenant-unit) can be a hybrid integration of a PON architecture with a traditional local distribution such as DSL and cable modem at customer premises (MDU or MTU). With the combinations of various evolving optical broadband access networks and technologies [4], we expect that the fiber-to-all-users can become a reality in the very near future.

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