Using Millimeterwave Technology in Metropolitan Area Networks

Millimeterwave technology offers a cost-effective alternative for linking bandwidth-hungry customers to fiber optic infrastructure.

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The United States currently faces a &quotlast mile&quot challenge, with less than 5% of commercial buildings having access to the high-speed fiber backbone. As more companies use the Internet for communications and sales vehicles, a link to fiber will become an essential aspect of business operations.

Traditionally, telecommunications companies have used microwave radios as a complement to physical copper lines for voice and data services. These microwave communication systems were limited in bandwidth, primarily due to FCC's limited bandwidth allocation and the difficulty in providing carrier-class quality while performing complex radio modulations. Recent developments in millimeterwave radio technology are starting to replace the microwave communications systems. The millimeterwave technology, coupled with the FCC's allocations of unlicensed spectrum, offer more cost-effective alternative for linking bandwidth-hungry customers to the fiber optic infrastructure.

Internet-style, or shared data communications architectures have been deployed to link users via wireless devices, such as the 60 GHz radio, GigaLinkK&#153. Wireless networks operating at the unlicensed spectrum of 60 GHz solve the last mile problem and enable a low-cost implementation of a fiber-speed synchronous (SONET) or IP based network in metropolitan areas.

The use of the 60 GHz unlicensed spectrum provides many benefits. Due to the high bandwidth needs of successful metropolitan area networks, the data rates of the new millimeterwave radio systems must be higher than that of earlier microwave and millimeterwave radio systems. With a fast RF modulator, new millimeter frequency radio waves can be modulated up to 3,500 MHz while minimizing the transmission latency normally associated with more complex modulation schemes, such as Quadrature Amplitude Modulation (QAM).

Effects From Weather Conditions

Weather conditions have an adverse effect on all forms of RF transmission, especially in the millimeterwave region in which severe rainstorms can cause as much as a 20 dB loss in signal strength for every kilometer. Therefore, as the distance the radio reaches increases, the fade margin needed to compensate for weather effects increases proportionately.

In addition to the attenuation from weather conditions, a 60 GHz radio system must also overcome the effects of oxygen absorption, 16 dB/KM, in the spectrum. In order to operate effectively, a very focused, narrow-beam antenna must be employed. Additionally, the radio system must be deployed in links with distances of approximately one kilometer. The combination of very narrow beam antennae and short transmission ranges work together to increase immunity to weather caused fades and interference from same frequency systems. These factors also enhance the security of the 60 GHz radio link, minimizing the probability of unauthorized intercept of transmissions.

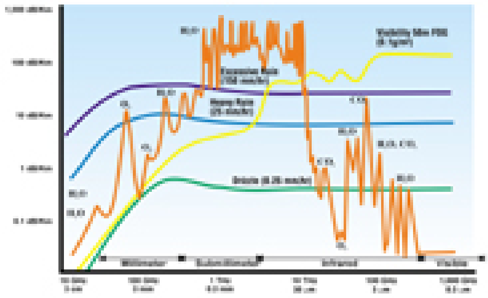

Figure 1. Atmospheric Attenuation Characteristics for Wavelengths 3 cm to .3 mm

At 60 GHz, the extremely high atmospheric absorption is due to the molecular composition of the terrestrial atmosphere. Figure 1 illustrates the atmospheric attenuation characteristics for wavelengths from 3 cm to 0.3 mm. For millimeterwaves, 30 GHz and above, the primary absorption molecules are H_2O, O_2, CO_2 and O_3. Since the presence of O_2 is fairly consistent at ground level, its effect on 60 GHz radio transmission is easily modeled for margin budgeting purposes. In addition, the high level of attenuation from oxygen absorption makes even the worst weather-related attenuation insignificant, especially on short paths. Even extremely heavy rainfall, 5 dB/Km at greater than 25 mm per hour, has a very small percentage contribution to aggregate attenuation in the 60 GHz oxygen absorption region.

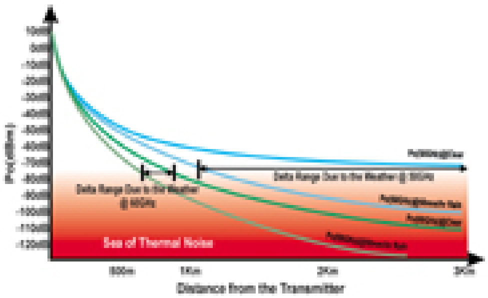

Figure 2. Effective Transmission for Various Weather Conditions

Figure 2 details the range calculation diagram for 60 GHz, the oxygen absorption band and a 50 GHz radio with 15 mW antenna injection power with focused antennae, 30 dBi with 3.5 &#176 beam width.

A comparison of 60 GHz and 50 GHz radio transmissions is useful to illustrate the unique properties of the oxygen absorption spectrum. The frequencies of 50 and 60 GHz are almost identical in terms of free space propagation, but the 50 GHz frequency falls outside of the O2 absorption range. The 50 GHz radio can reach as far as 5 Km on a clear day while the range shrinks to 1.2 Km under the 50 mm per hour rainfall. This represents a difference in useful range of nearly 300 percent. Although the 60 GHz radio signal cannot carry reliably beyond 800 M even in ideal weather, a 50 mm per hour rain will shorten the range to 600 M; only a 20 percent reduction in range.

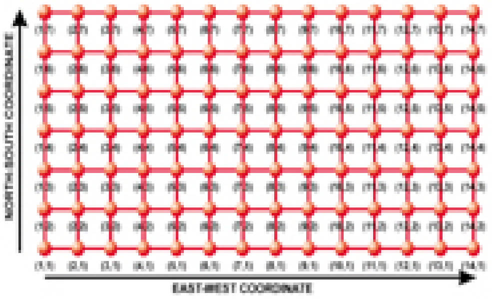

Figure 3. A Typical Layout of Office Buildings

Figure 3 illustrates a typical suburban commercial zone with space for office, hotel and industrial buildings located near interstate highways. Fiber optic cable trunks have already been installed along the highway's right-of-ways within a short physical distance of the business park. The X symbol identifies buildings with the 60 GHz radio communications systems. The first office building is located within 200 M of the interchange and physical fiber trunk. Along the access road to the interchange, there are contiguous regions of office buildings, most of which are less than 100 M apart.

Because of the 60 GHz radio system's extremely high data capacity, it can easily accommodate many users, allowing for small multi-building networks. The wireless host whose location is closest to the fiber trunk becomes the seed for generating a fiber-speed, wireless network. Each additional subscriber has the ability to daisy chain links to the seed subscriber at a minimal cost.

Orderly planned growth of the wireless 60 GHz network can extend further the possibility of the wireless network over a metropolitan area. Real-time applications, such as teleconferencing, live video broadcasts and voice services now have become a reality.

Routing Network

The proposed metropolitan area network would incorporate many switches over a large area. Every switching point would result in an accumulated delay. The limitations of the traditional packet exchange mechanism, a rather large switching delay-milliseconds-pose problems for metropolitan area networks. These individual switching delays combined with each additional switch would eventually reach an aggregate where real-time applications would become unrealistic. Considering this propagation delay and as many as 1000 switches, the acceptable switching delay at each point must be held to under 100 microseconds.

By matching the network address with the geographic network topology, the switching delay would be significantly decreased. A simple two-dimensional grid over ATM cells can be routed in real-time. Figure 4 illustrates the vector routing algorithm.

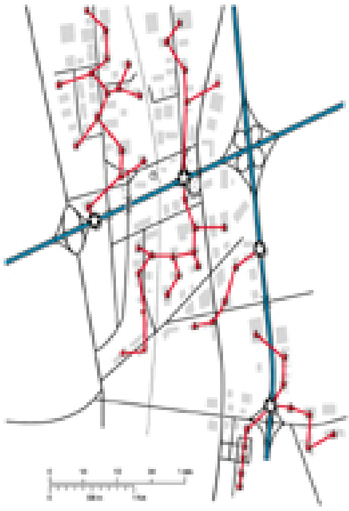

Figure 4. Matching the Network Address and the Network Geographic Topology

With this vector routing algorithm, the grid network has a throughput of the bandwidth available to each port. The vector consists of the difference between the simple vector routing that uses its destination, and the current node address the data cells are fed to the local port if this vector is equal to zero. If the vector is not equal to zero, the cell is routed to the nearest routing point by the vector. Since the vector does not have to look up the destination address, a Banyan-type switch in real-time can accomplish the routing.

Network Rerouting

With a small subscriber base, 155 Mbps of bandwidth would satisfy the anticipated network traffic. However, a successful subscriber volume with heavy traffic and usage requires additional fiber and radios. At the point of heavy traffic, a dynamic rerouting algorithm as shown in Figure 5 must be implemented. The dynamic rerouting uses an OEM cell to convey traffic conditions to the immediate neighboring nodes. The percentage of traffic at the neighboring node is used as a rerouting phase. The level of congestion is used as the rerouting component. The dynamic rerouting allows massive throughput over the network, which is twice the bandwidth of the medium that feeds to the arbitrary nodes throughout the network. In most point-to-point traffic situations, this scheme works extremely efficiently.

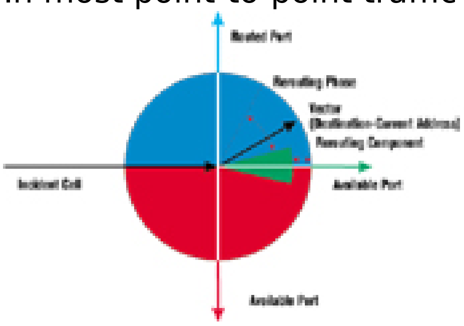

Figure 5. Vector Routing with Dynamic Rerouting

In a recurrent feedback system, like the one with dynamic vector rerouting, the system is chaotic. This chaotic behavior becomes apparent when the majority of the nodes try to feed data to a single node or neighboring block of nodes. This point becomes a Lorenz point, or the strange attractor. In order to avoid the network falling into the fibrillation mode, a supervisory station capable of assigning priorities and distributing a correction vector throughout the system must be included in the feedback network.

The supervisory station is analogous to an intelligent pacemaker that keeps the heart from falling into a random timing state. The network throughput will be improved by implementing spot transfer stations to relieve congestion.

Furthermore, the central station can be used as a broadcast point. A public event often causes repetitive distribution of the same data over multiple locations. Digital broadcasts from a central location dramatically improve the network traffic under such conditions.

The installation of a fiber network without guaranteed subscribers is a high-risk and high-cost proposition. The metropolitan area network utilizing fiber-speed, wireless devices allows high-speed communications without such risk for cost-effective creation of small, multi-building networks.

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