Fiber-wireless (Fi-Wi) to provide ultra-high-speed, short-range communication

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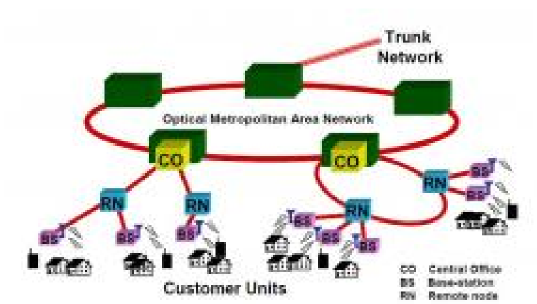

A mm-wave Fi-Wi network. An optical fiber backbone (red) provides broadband connections between the central offices and antenna base stations. Then, the base stations wirelessly transmit 5-mm-wave (60 GHz) signals to customers. Within buildings and homes, the short-range wireless signals can provide high-speed connectivity (faster than 1 Gb/s) for a variety of wireless, high-bandwidth communication devices. Credit: Lim, et al.

(PhysOrg.com) -- By looking at the latest electronic communication devices that have emerged over the past few years, it's clear that the trend of smaller, portable devices is strong and expected to continue. Yet while all these notebooks, netbooks, and tablet PCs are becoming more and more popular, their explosive growth also poses a problem: these wireless devices are hogging the already congested lower microwave frequency region of the wireless spectrum.

This congestion problem was not unanticipated by electrical engineers, who, for the past two decades, have been developing new wireless technologies that use different parts of the electromagnetic spectrum. Specifically, these wireless technologies are exploiting the large, unused bandwidths of extremely high frequency (EHF) microwaves in the millimeter-wave (mm-wave) frequency region. One particular area of interest is the unlicensed 60 GHz frequency band, which has 5-mm wavelengths. (In contrast, the heavily burdened lower microwave regions have frequencies of 2-4 GHz, corresponding to wavelengths of 7.5-15 cm.)

However, the 60 GHz frequency band is not without challenges, either. Since wireless signals at 60 GHz frequencies have inherently high propagation losses, they are targeted toward short-range, in-building, high-speed applications. To maintain strong incoming wireless signals for buildings, many antenna base stations must be built near customers. These base stations, in turn, would receive broadband signals from a smaller number of distant central offices. The signals between central offices and base stations would be transmitted through long-range optical fibers. Since such a system uses both optical fibers and mm-wave wireless transmission, the technology is called “fiber-wireless” (Fi-Wi).

The advantage of bimodal Fi-Wi systems is that they can enjoy the strengths of both optical and wireless technologies - specifically, the inherently large bandwidth of optical fiber and the large, unused bandwidth in the mm-wave wireless spectrum. For this reason, a hybrid system has the potential to provide very high data transmission rates with minimal time delay.

Recently, a team of electrical engineers working on fiber-wireless technologies has analyzed the progress made in this field over the past two decades. In a paper published in the *Journal of Lightwave Technology*, Christina Lim, from the University of Melbourne, and her coauthors have presented an overview of the many different techniques proposed to optically transport mm-wave wireless signals and overcome some of the challenges involved.

“Mm-wave frequency allocation around 57-66 GHz can deliver bandwidths in excess of 1 Gb/s compared to few Mb/s offered by current third generation mobile systems or 100 Mb/s offered by Wi-Fi systems,” Lim told *PhysOrg.com*. “There are even higher mm-wave frequencies which have much larger bandwidths available. However, the technologies for these are not yet matured and over time, the mm-wave band could be exploited to give bandwidths in excess of 10 Gb/s over short-range wireless.

“Due to the short transmission distances associated with mm-wave frequencies, applications in personal area networking would be the most appropriate,” she said. “Providing fast wireless connectivity between your hi-def display screens and video content on a storage device, for example, or connecting a range of devices such as laptops, media storage and displays for entertainment and business interactivity applications, to name a few, will soon require bandwidths in excess of 100 Mb/s connectivity.”

Transportation and integration options

Regarding the basic architecture of a Fi-Wi system, the researchers looked at three possible approaches for transporting mm-wave wireless signals over optical fibers. The simplest scheme, called RF-over-fiber, involves directly transporting the wireless signals, so that no frequency translation is required at the base stations. The second method involves downconverting the mm-wave wireless signals to a lower intermediate frequency (IF) at the central office before optically transmitting the signals to the base station where they are upconverted, which is called IF-over-fiber. The third method, called baseband-over-fiber, involves transporting the wireless signals as very low-frequency baseband signals over optical fibers from the central office to the base station, and then upconverting the information to the mm-wave frequency at the base station.

Ultimately, there is a tradeoff between simplicity and robustness in the three methods: while the RF-over-fiber method is the simplest, the signals are more susceptible to various impairments as they propagate along the optical fiber. Many research teams have been working on a number of strategies to overcome these impairments. The authors of the current study emphasize that these improvements are necessary for achieving good signal quality and overall system performance.

Another requirement is for fiber-wireless systems to be integrated with the existing optical infrastructure. The engineers explain that the rising level of optical fiber infrastructure deployment close to residential premises provides an ideal opportunity to interconnect the wireless with fixed wired networks. This integration would enable fiber-wireless systems to take advantage of current technologies such as wavelength-division-multiplexing (WDM), which combines multiple signals on a single optical fiber by using different wavelengths. Previous research has demonstrated that WDM can significantly increase the capacity and success rates of fiber-wireless systems. In addition, research has shown that there are a range of technology options that support such integration cost-effectively without compromising the performance required of these very high-speed networks.

Overall, mm-wave fiber-wireless technology has the potential to open up the wireless spectrum as the use of small, portable communication devices continues to grow. Serving as a short-distance technology, the wireless portion can cover the "last mile" of data transmission to customers, as well as in-building networking, with the potential for faster speeds and lower costs. For these reasons, fiber-wireless systems would make the most sense in densely populated areas, and also for disaster recovery environments where wired communication lines are unavailable. As Lim explained, fiber-wireless could be deployed in the near future.

“We feel that fiber-wireless could be commercially ready in 3-5 years with immediate applications to new base station installations,” she said. “The adoption of Fi-Wi technologies to 3G and 4G wireless will be the most likely market in the immediate term. As the fiber deployment extends to buildings and premises, mm-wave Fi-Wi will take off.”

More information: Christina Lim, et al. “Fiber-Wireless Networks and Subsystem Technologies.” *Journal of Lightwave Technology*. Vol. 28, No. 4. February 15, 2010. Doi:10.1109/JLT.2009.2031423