Record-breaking signal transmission capacity paves the way for faster Internet

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The amount of data traffic on the internet and between servers in datacenters has exploded in the past few decades and shows no signs of slowing down. For example, Ethernet technology, used in small to medium-sized networks, has evolved from an original speed of 2.94 megabits per second to 100 gigabits per second, an increase of more than 3,000-fold. An IEEE 400 Gb/s Ethernet Task Force has been formed to take the standard up to 400 gigabits per second in the next year or so, and even this may not be enough for some especially data-heavy companies.

Now, researchers from ZTE USA, Inc., New Jersey, USA, have set a new capacity record for a certain type of optical fiber link that could be used to connect segments of the internet, as well as connect servers in a datacenter. The team sent 560 gigabits per second over two kilometers of single mode optical fiber, a type of fiber used for long-distance links. The researchers' solution is a low-cost and low-power optical solution that hinges on a unique combination of modulation techniques, which are used to encode digital data in an analog carrier, like light. The researchers will present their innovation at the Optical Fiber Communication Conference and Exhibition (OFC), held 20-24 March in Anaheim, California, USA.

Sending data over optical cables, as opposed to traditional coax cables or copper wires, can achieve much higher data densities and longer distances. Moreover, optical links are unaffected by electromagnetic interference and consume less power, which is becoming increasingly

important as data rates continue to rise. However, the standards for encoding data in optical signals will need to evolve in order to meet increased demand for bandwidth hungry applications.

"For the existing optical network [used in industry], the modulation format is still On-off keying (OOK), which is impossible to realize 100 gigabits per second or beyond in optical inter-connection due to devices' bandwidth limitation," said Fan Li, primary author and scientist, ZTE USA, Inc. On-off keying refers to the simplest form of amplitude modulation that represents digital data as the presence (binary one) or absence (binary zero) of the signal.

Li explained that their scheme adopts a higher level, broadband multicarrier modulation method called Orthogonal Frequency-Division Multiplexing (OFDM), which transmits multiple data streams over a common broadband medium such as fiber optic cable and offers superior performance such as higher data capacity and faster data transmission speed in a given bandwidth over older, more traditional single-carrier modulation methods.

"400 gigabits per second is the next generation transmission speed for optical inter-connection. It's the first time we realize 560 gigabits per second signal transmission with OFDM technology," Li said.

Jianjun Yu, Director, ZTE USA, Inc. explained that the OFDM modulation method is suited to today's high-speed data requirements and operation in the ultra-high frequency and microwave band, and thus have been adopted for almost all the new wireless technologies nowadays. However, OFDM does have a drawback: a large peak-to-average power ratio (PAPR), meaning the instantaneous peak power of an OFDM signal is much bigger than the average power due to the coherent addition of multiple data streams or subcarriers. This characteristic leads to poor network performance at high frequencies due to the inter-

connect power attenuation.

In order to improve the inter-connect performance, the researchers employed a special case of OFDM called Discrete Fourier Transform-spread (DFT-spread) orthogonal frequency-division multiplexing (OFDM), and a technique implemented in the calibration stage called Pre-equalization, which jointly overcome power attenuation in high frequency domain and reduce the peak-to-average power ratio of OFDM.

Another key part of the experimental configuration is a four-channel coarse wavelength division multiplexing (CWDM) scheme, which effectively realizes low-cost, low-power and high capacity transmission for optical signals in the inter-connection. "Coarse" means the channel spacing is more than two nanometers.

Combined with 128-QAM Orthogonal Frequency-Division Multiplexing (OFDM) – a high order OFDM modulation format for electric signals – the four-channel coarse wavelength division multiplexing (CWDM) architecture achieves the highest data transmission capacity within the same bandwidth. Each channel transmits 140 gigabits per second 128-QAM OFDM signals, for a total of 560 gigabits per second from four channels.

"Our study is the first to use Discrete Fourier Transform-spread (DFT-spread) orthogonal frequency-division multiplexing (OFDM) technology to realize optical inter-connection and achieve the largest capacity signal transmission ever reported," Li said. "The experimental results indicate that it is feasible to utilize the transceivers to realize cost-effective two-kilometer single fiber mode (SFM-28) link to satisfy the 400-gigabit Ethernet standard."

Li noted the potential application of the novel configuration lies in

communication between transport networks and core routers, important components of the internet, as well as faster communication within datacenters. "For example, companies like Google or Amazon use different high-performance servers to sort high volumes of customer profiles and other useful information. The data exchanges between these servers are large and frequent, [so] high speed and high transmission capacity optical inter-connection is a good candidate for the datacenter."

The researchers' next step, Li said, is to reduce the computational complexity in the configuration and realize a real application-specific integrated circuit (ASIC) system.

More information: Presentation: "Demonstration of Four-Channel CWDM 560 Gbit/s 128QAM-OFDM for Optical Inter-connection," by Fan Li, Zizheng Cao, Xinying Li, and Jianjun Yu.

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