



# File Transfer

## DF Raptor™ Technology Overcomes The Bandwidth Inefficiencies of TCP/IP

Over IP networks, TCP (or TCP/IP) is the protocol most commonly used to support reliable file transfer. For example, application-layer protocols such as HTTP, FTP, and Telnet are all based on TCP. With TCP, however, reliability is realized at the expense of bandwidth efficiency. Digital Fountain's DF Raptor™ technology, in contrast, ensures reliability but still allows full use of all available bandwidth.

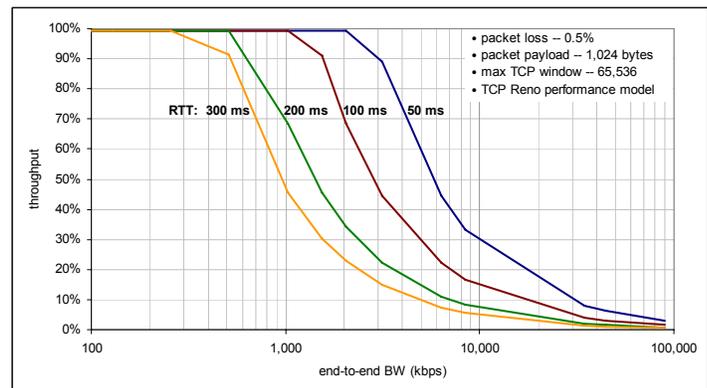
DF Raptor forward error correction (FEC) technology overcomes TCP's bandwidth inefficiencies by providing an alternative way to reliably transfer data over an IP network that maximizes throughput and fully uses available bandwidth regardless of network congestion, packet loss, or latency. DF Raptor FEC offers file transfer with:

- Accelerated transfer time
- Efficient bandwidth utilization
- Ensured reliability
  - Robust performance in the presence of packet loss, latency, and/or congestion
  - Guaranteed complete and error-free data delivery
- Reduced cost – better use of network resources
- Adaptability to changing network conditions
- Minimum processing requirements
  - Can be implemented as an integrated or stand-alone software solution
  - Lightweight software implementation

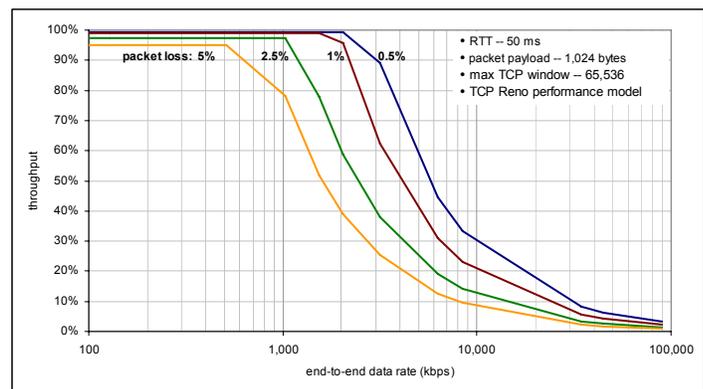
### What's Wrong With TCP?

TCP is a connection-oriented end-to-end reliable transport protocol that establishes sessions between the two communicating ends. In order to provide reliability, TCP uses sequence numbers, checksums, positive acknowledgements, timeouts, and retransmissions.

TCP's flow control and congestion avoidance mechanisms monitor the round-trip time between the transmitter and receiver, assuming that long round-trip times are due to network congestion rather than actual transit times. TCP requires the receiving end to acknowledge successfully received packets and the transmitting end to retransmit any packets that have not been acknowledged within a timeout period. TCP then responds to any unacknowledged packet by slowing down the flow of data packets to reduce the throughput as a way to ease the assumed congestion. As a result, file transfer between two distant points over a WAN using TCP is unable to take advantage of the available bandwidth, creating lengthy transmission times.



*TCP cannot use all available bandwidth in the presence of long round-trip times (DF Raptor FEC throughput is 99.5% for all data rates in this example)*



*TCP reduces the achievable throughput in the presence of packet loss (DF Raptor FEC throughput is 95-99.5% for all data rates in this example)*

TCP uses the mechanism of the TCP window size to control the throughput. The TCP window size defines the amount of outstanding data -- data unacknowledged by the receiver -- that can be transmitted before some of the data is finally acknowledged. With 100% throughput, the maximum unacknowledged data that can be *en route* between the transmitter and the receiver is equal to the round-trip time multiplied by the end-to-end data rate. In its operation, TCP continually estimates this amount, setting the TCP window size at the transmitter to control how much data is sent before an acknowledgement is received. If an expected acknowledgement is not received because of packet loss, then the window size is reduced. If communications are thereafter successful, the window size is slowly increased to its maximum value. This cycle – repeatedly reducing and slowly increasing the TCP window size when acknowledgements are not received -- continues throughout the TCP session.

If packet loss triggers reduction of the window size as TCP operates, then the achievable throughput becomes a function of the packet loss rate and the round-trip time. By design, TCP will reduce the rate at which packets are transmitted in a misguided attempt to moderate network congestion. As a consequence, bandwidth is not fully utilized, and the time it takes to transfer a file from point-to-point over TCP is much longer than it need be.

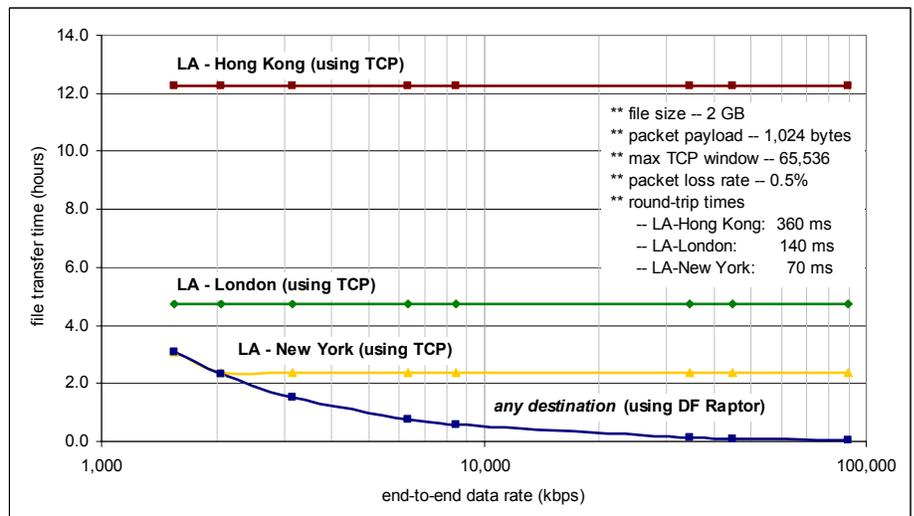
### How Can Using DF Raptor FEC Do Better Than TCP?

With DF Raptor technology, however, reliability can be ensured while maximizing the use of bandwidth. Because DF Raptor FEC guarantees the ultimate recovery of any lost or corrupted packets, the transport protocol does not need to provide reliability, and file transfer can make full use of the end-to-end data rate. As a result, DF Raptor technology can save time, money, and network resources.

For example, if UDP rather than TCP is employed to deliver DF Raptor-encoded packets, then the inefficiencies of TCP are not incurred. UDP is a connectionless protocol that, unlike TCP, does not involve any initial handshaking to establish a link between the source and destination and does not attempt to provide reliable communications. A connectionless protocol like UDP can realize throughput levels that approach the end-to-end bandwidth because it neither consumes bandwidth with acknowledgements and re-transmissions nor restricts the amount of data that can be transmitted.

UDP, however, does not provide reliability and will allow individual packets to be lost or delivered out of sequence. But if the packets are DF Raptor-encoded, the DF Raptor FEC algorithm will supply the necessary reliability to ensure that the data is received completely and in the correct order. In this way, the efficiencies of a connectionless protocol can be combined with the reliability provided by packet-level DF Raptor FEC protection.

The advantages of using DF Raptor FEC (and not using TCP) to support file transfer are especially evident when large files are to be transmitted over great distances. International or transcontinental routes will necessarily involve relatively large round-trip times, and, if any packets are dropped, TCP will respond by strictly limiting the transmission rate. With TCP, increasing the available bandwidth does not reduce the file transfer time. With DF Raptor FEC, in contrast, the time required to transfer a file diminishes as the data rate increases – DF Raptor technology allows network resources to be fully utilized.



*DF Raptor FEC can take full advantage of the available bandwidth in transferring a 2GB file, while TCP incurs long transfer times that reflect the round-trip time to the destination*

## ***DF Raptor FEC Technology***

DF Raptor technology is the world's most advanced FEC for data networks.

DF Raptor FEC is an erasure correction code, capable of correcting "missing" or "lost" data. By recovering lost data packets without requiring retransmission from the sender, a DF Raptor code efficiently and effectively provides reliability in data networks. And, like a water fountain producing an endless supply of water drops, any of which can be used to completely fill a glass, a DF Raptor code is a fountain code (a "digital fountain") that can generate an unlimited number of encoded output symbols, any of which can be used to recover the original input symbols.

- DF Raptor technology provides extraordinary protection against packet loss. As a fountain code, DF Raptor FEC can dynamically generate as much protection as needed for any amount of loss.
- DF Raptor technology offers optimal performance. Bandwidth expansion and overhead can be minimized without sacrificing the level of loss protection.
- DF Raptor technology is exceptionally efficient. The computational requirements of DF Raptor FEC scale linearly with the amount of data being processed, unlike other FEC alternatives for which the complexity typically increases with the square of the data. As a consequence, DF Raptor technology can be readily implemented in software and supported by a general-purpose processor.

### ***Company Background***

Qualcomm develops and licenses advanced FEC technology to enhance the quality of content delivery over data networks. Qualcomm's patented DF Raptor technology improves streaming media quality, ensures timely delivery of data, and enables the creation and development of new communications services. DF Raptor technology is used today in a variety of consumer, military, and enterprise devices and applications, supporting both wired and wireless telecommunications networks.

### ***More Information***

For more information, please visit [www.qualcomm.com/raptor](http://www.qualcomm.com/raptor) or contact [raptor-info@qualcomm.com](mailto:raptor-info@qualcomm.com).

