USB 2.0 Actual Data Throughput Analysis

1. USB 2.0 Theoretical Speed

- **480 Mbps** (Megabits per second) = **60 MB/s** (Megabytes per second)
- This is the **raw signaling rate** and does not account for protocol overhead.

2. USB 2.0 Effective Data Throughput

The actual usable data rate is lower due to several factors:

Factor	**Explanation**	**Overhead Impact**
Packet Overhead	USB uses **frames and packets**, with headers, CRCs, and handshakes.	Reduces efficiency.
Polling-based Protocol	USB 2.0 uses a **host-driven** mechanism, adding latency.	Slower than true full-duplex protocols like PCIe.
Bulk vs Isochronous Transfer	Bulk (e.g., file transfers) has error correction, while Isochronous (e.g., audio/video) has **no retransmission**.	Bulk transfers lose some bandwidth to retries.
Host Controller Bottleneck	Some host controllers and USB hubs introduce additional processing delays.	Can further reduce speed.

3. Typical Real-World USB 2.0 Speeds

Based on different transfer modes:

Transfer Type	Max Achievable Speed
Bulk Transfer (e.g., file copy, external drives, flash storage)	**35–40 MB/s** (~280–320 Mbps)
Isochronous Transfer (e.g., audio, video streaming)	**30–35 MB/s** (~240–280 Mbps)
Interrupt Transfer (e.g., keyboards, mice)	Very small (~1 Mbps or less)

Real-world throughput is around 35–40 MB/s (~280–320 Mbps) in best cases.

4. Why Can't USB 2.0 Reach 60 MB/s?

1. **Packet and Protocol Overhead** → USB frames contain headers, checksums, and acknowledgments.
2. **Half-Duplex Communication** → USB 2.0 **cannot send and receive data at the same time**.
3. **Host Polling** → Unlike PCIe or DMA, USB **requires the host to initiate transfers**.
4. **Device & Driver Limitations** → Not all devices can utilize full bandwidth efficiently.
5.

5. Summary

- **USB 2.0 Raw Speed = 480 Mbps (60 MB/s)**
- **Real-World Throughput = 35–40 MB/s (~280–320 Mbps)**
- **Bulk Transfers (e.g., SSDs, HDDs) reach ~40 MB/s max.**

- **Isochronous Transfers (e.g., webcams, audio) are slightly lower due to no error correction.**