

# Exaflood Optics

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**10<sup>18</sup>**

# Good News from US in 2009!

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- Since 2000
  - US residential bandwidth grew 54X
  - US wireless bandwidth grew 542X
  - Total consumer bandwidth grew 91X
  - Total per capita consumer BW grew 84X
  - *Total traffic reached 1.5 Exabytes per month, 18 exabytes per year*

# Global Good News

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- Global traffic grew to more than double US
- Roughly 50 Exabytes per year
- Up at least 50fold since 2000.

# An Exabyte

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- The Library of Congress holds 20 million big books (400+ pages, measured as text)
- Every 400 pages is approximately 1 megabyte
- The Library of Congress contains 20 terabytes, or 20 million books.
- 1 exabyte is 50,000 Libraries of Congress

# Phases of the Internet

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- **Phase One**
  - Arpanet in 1969: connected a few thousand scientists and enthusiasts
- **Phase Two**
  - Circa 1995, the World Wide Web, the graphical browser, and e-mail brought the Net to the masses
- **Phase Three**
  - Now, video and rich media are changing the nature – and volume – of Net traffic

# US Internet Traffic

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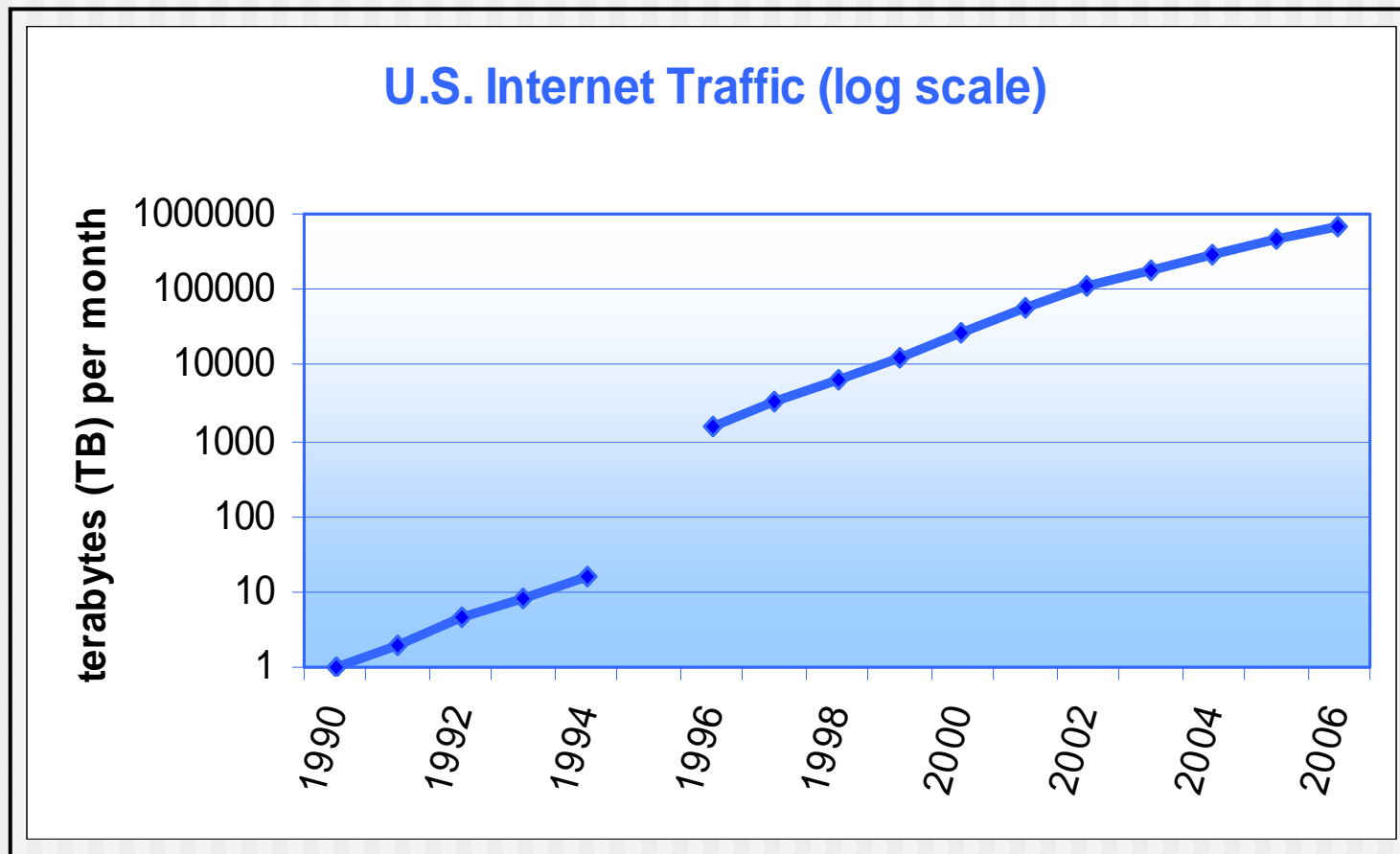
## Through 1996

- 1.5 Petabytes (PB) per month
- 18 Petabytes per year

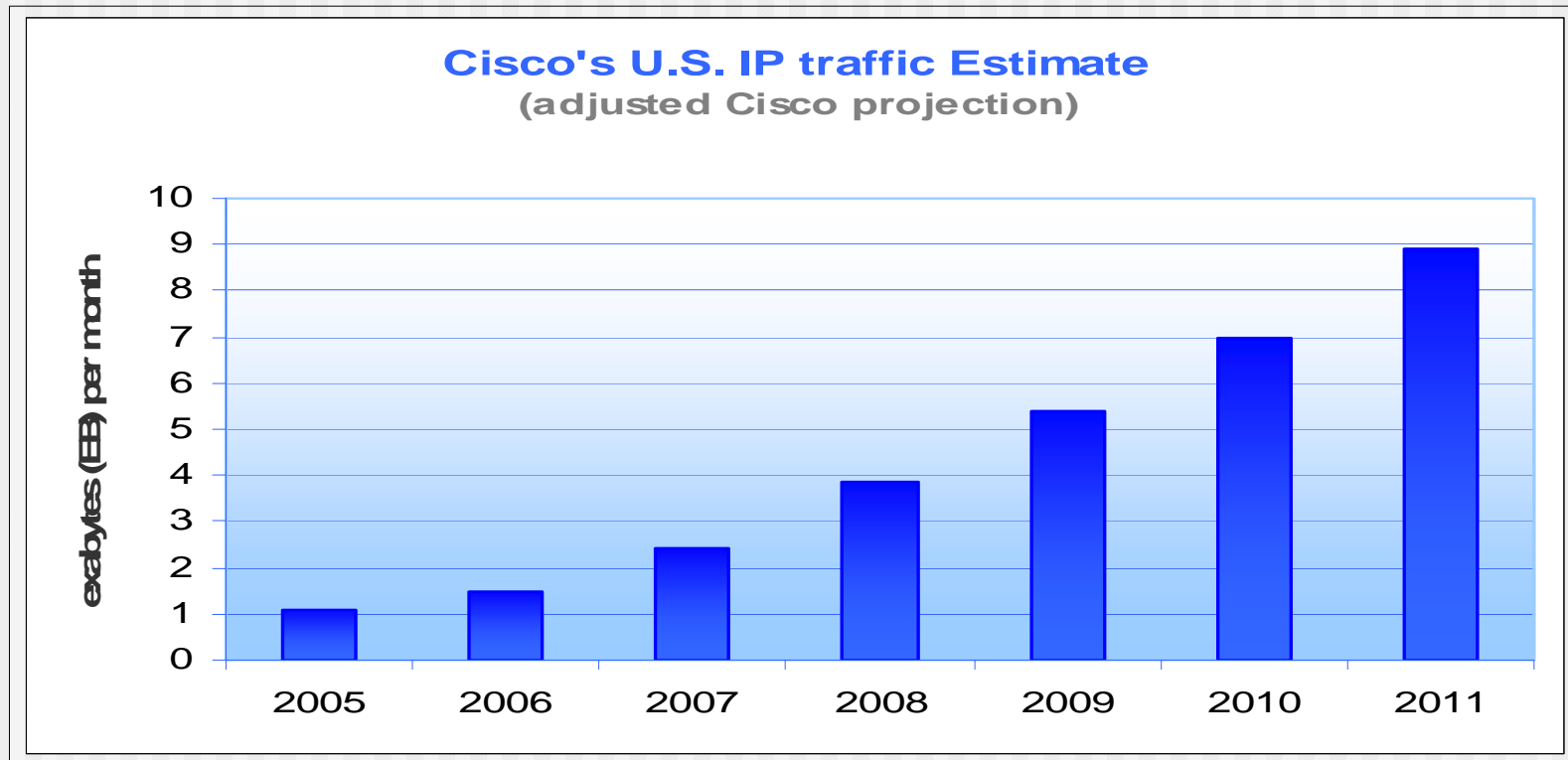
## Through 2008

- 1.5 Exabytes per month.
- 2009 run rate of 20 Exabytes per year.
- **Global** roughly 2.5X US: 50 Exabytes per year.

# US Internet Traffic



# US Internet Traffic by 2011



Cisco estimates U.S. Internet traffic of 6 exabytes per month by 2011, or ~72 exabytes per year....World Internet traffic could reach 11 exabytes/mo

# Life After Television

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## YouTube

- 100 petabytes per month in 2008
- 1.2 exabytes per year, roughly 7% of U.S. Internet traffic
- All original broadcast and cable TV and radio content adds up to ~100 petabytes per year
- YouTube streams that much data in a month
- a HI-DEF YouTube would mean 17 exabytes per year, or roughly equal to the entire U.S. Internet

# Life After Television

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## Video Conferencing

- MSN Messenger Video Calling in mid-2007 generated 4 petabytes per month
- = to the entire Net in 1997
- Cisco's new Telepresence requires 15 Mbps symmetrical bandwidth
  - A one-hour conference call = 13.5 gigabytes
- 30 exabytes of telephone traffic each year

Kilo –  $10^3$

Mega –  $10^6$

Giga –  $10^9$

Tera –  $10^{12}$

Peta –  $10^{15}$

Exa –  $10^{18}$

Zetta –  $10^{21}$

# Life After Television

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## Zettabyte HD

- Move to video-phones would mean 400 exabytes – *at least* – in the U.S., or 10x the size of the existing world Internet
- With HD, more than 2 zettabytes

Kilo –  $10^3$

Mega –  $10^6$

Giga –  $10^9$

Tera –  $10^{12}$

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# Life After Television

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## **Impromptu Video/ Motion Pictures**

- 10 exabytes of amateur video each year
- conversion to HD would mean 100 exabytes per year, or 3x today's annual world Internet traffic
- one Blu-ray HD movie is ~ 25 GB
- With HD, NetFlix today would ship 5.8 exabytes of DVDs each year
- American HD movie downloads could generate 100 exabytes per year, or 2x today's world Internet

# Life After Television

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## Online Gaming and Virtual Worlds

- Graphics chips from AMD-ATI and Nvidia make 3D gaming and virtual worlds a possibility for first time
- Otoy makes possible real-time 3D rendering and mass- and peer-to-peer distribution of rich video
- One massively parallel game with 1 million players could generate 100 PB per month – more than an exabyte a year.
- “Steam” game downloads has 13 million subscribers

# Life After Television

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## **IPTV**

- Telcos and possibly cablecos moving to IPTV
- Last mile bandwidth must expand 10-100x to meet new IPTV challenges
- Hulu and competitors deliver free TV over the Net – 350 megabytes per hour
- NBC streamed 50 million of its TV shows in early 2008.

# Life After Television

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## Ultra High Def (UHDTV)

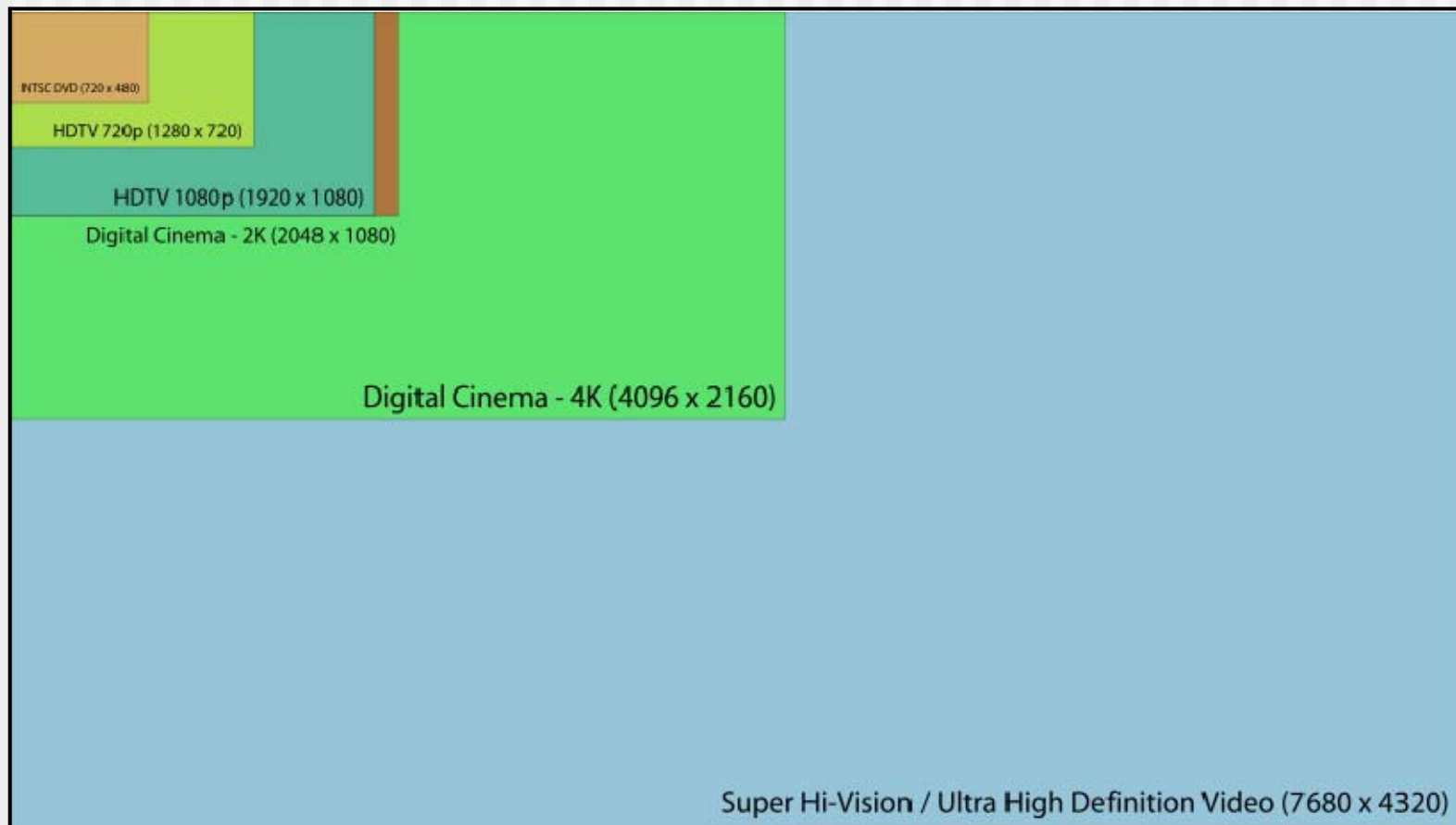
Circa 2016 – 7,680 x 4,320

- 33 megapixels @ 60 fps, or 16-32x the pixels/sec of HDTV
- Uncompressed two-hour movie ~ 25 terabytes
- MPEG4 two-hour movie ~ 360 gigabytes
- So all the HD numbers get multiplied by another 10x, which is 100x more than standard def video
- 100 exabytes of HD video becomes a zettabyte of 3D video

Kilo –  $10^3$   
Mega –  $10^6$   
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# UltraHDTV vs. HDTV

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# Global Sensorium

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## Imaging

- Mobile phone cameras
  - 3.4 billion mobile phones users in 2008
  - 1.5 billion *camera* phones sold in 2008
- Personal Cameras
  - 100 million compact digital cameras sold by 2009
  - 6 million high-resolution DSLR cameras sold by 2009
- Surveillance / Medical / Automobile / PCs
  - A *dozen* cameras on each city block or building entrance?
  - A *dozen* digital cameras in every automobile?

# Global Sensorium

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## **RFID – Radio Frequency Identification**

- We will be tagging many, many more things
- Unknown hundreds of billions of items enabled by IPV6
- How much information will these tags collect? How will we transmit and store this information?
- John Chambers says by 2000 we had connected 100 million devices
- By 2010 we will connect 14 billion devices to the Net

# Beyond Moore's Law

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## **Integrated Optical Devices**

- Implantation of thousands of lasers and photodetectors in silicon
- Direct optical bandwidth from chip to chip and across the Net

# Beyond Moore's Law

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## **Hard Disk Miracle: 2x Moore's law**

- \$500 bought 100 megabytes in 1991...today \$500 buys a 3 terabyte drive...meaning factor of over 30,000 gain in 18 years
- Continues with new Hybrid Disk storage, Ovonic Memory, and "Racetrack Memory"...
- Hi Def DVR – Seagate 3.5 inch hard-drive that holds 3 TB of HD video in 2010

## More Data in Smaller Space

The ability to store increasing amounts of data in a smaller space continues to revolutionize the consumer electronics industry with products that keep getting smaller and cheaper while providing more functions.

### HARD DISK DRIVE DENSITY



**1956** The 5-megabyte hard drive inaugurates the era of corporate data centers.

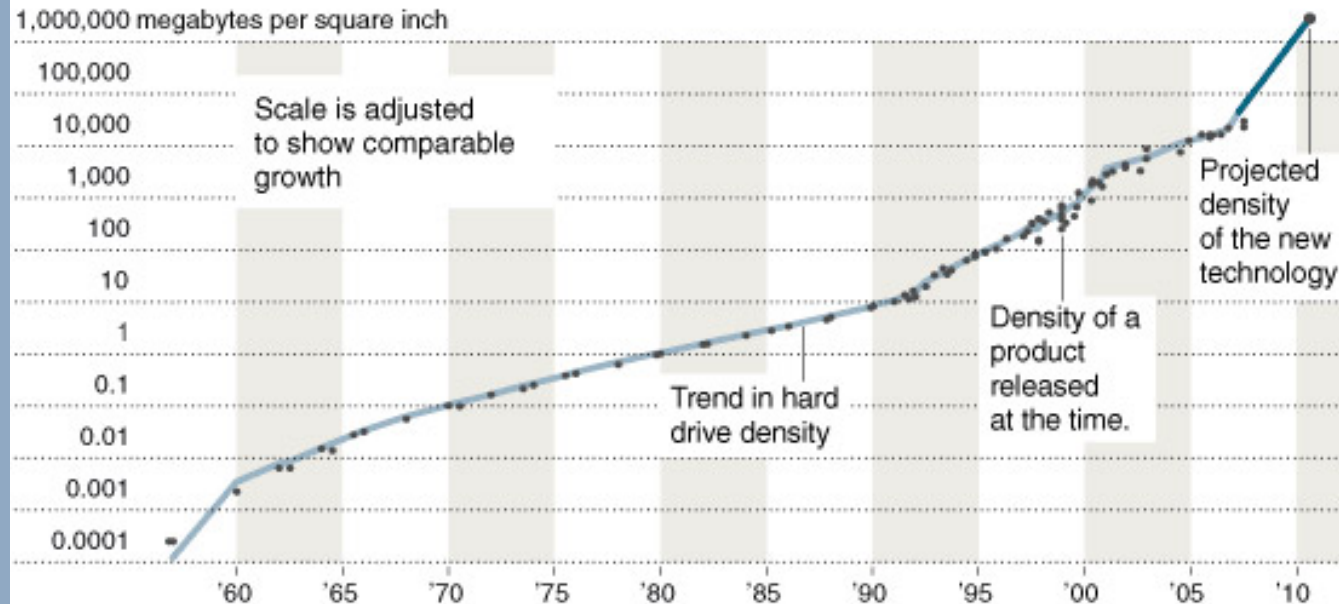
**1980** Shrinking the hard drive to 5.25 inches allows production of desktop computers.



**1988** The 3.5-inch hard drive is used in laptop computers.



**2001** The 1.8-inch hard drive makes portable digital music players possible.



Sources: IBM

# LAN's End

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## **Trusted Computing**

- Obviates firewalled LANs & virus software+passwords
- Allows all local traffic, storage, and apps seamlessly to flood the Internet

## **Dark Web**

- Says Cisco's John Chambers: Unconnected, firewalled, "Dark Web" data could be 500 times official Internet data

## **Network Computing / Web Services**

- Googleplex paradigm of centralized computing – applications move from PC to "the cloud"
- Hosted real-time applications will require robust connections of 25 Mbps+

# All Things Digital

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Annual worldwide digital information created, captured, and replicated (but not necessarily stored or transmitted):

**161 exabytes in  
2006**

**988 exabytes in  
2010 (est)**

Source: "The Expanding Digital Universe." IDC. March 2007.

# LAN's End

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## Peer to Peer

- File sharing – music, tv, home videos, podcasts

## Remote Backup

- 2 billion PCs
- 50 GB per PC (in the near future)
- 100 **exabytes**

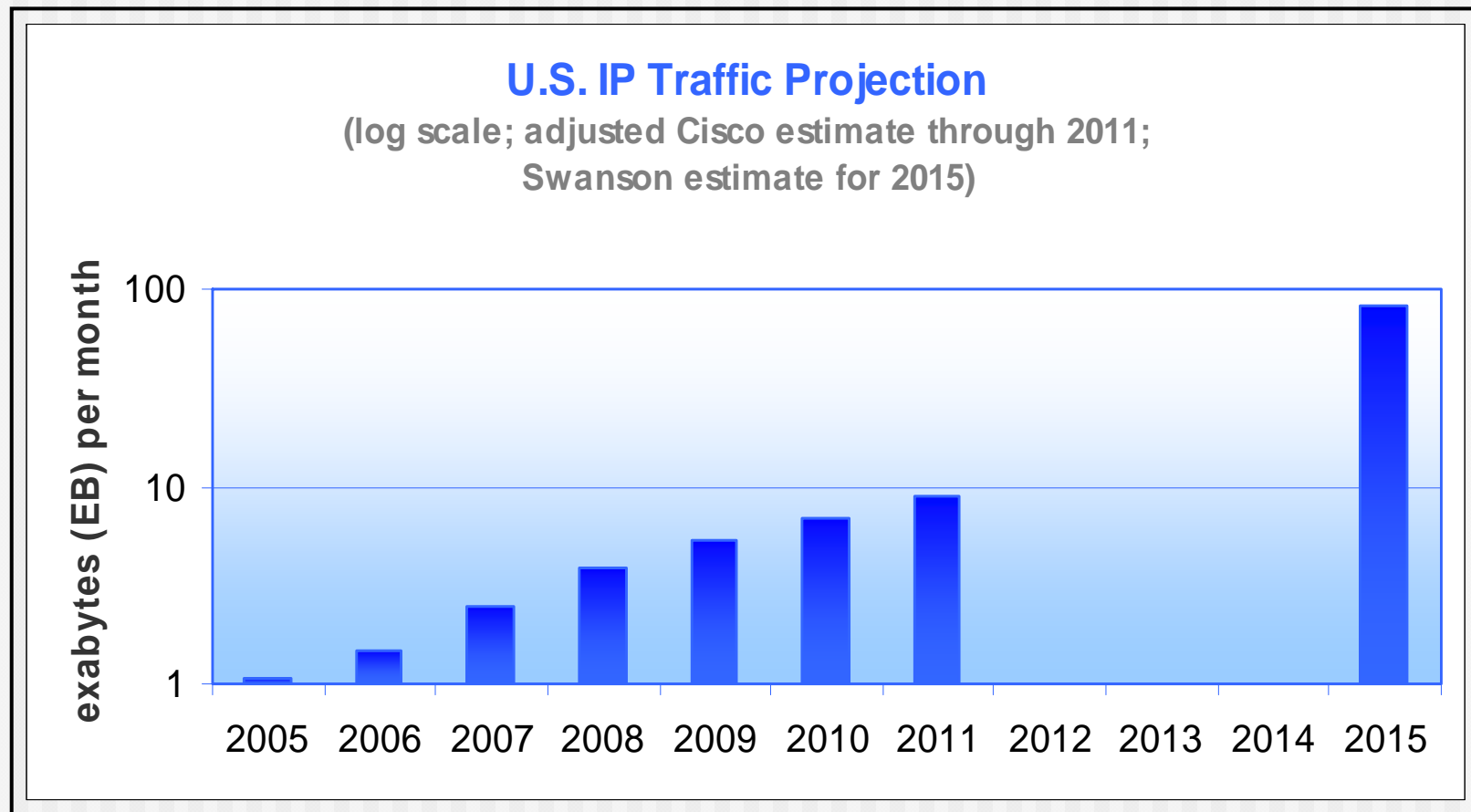
# Adding up the bytes

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Summing these trends, circa 2015, we project

- Movie downloads and P2P.....100 exabytes
- Video calling and virtual windows.....400 exabytes
- “Cloud computing” and remote backup.....50 exabytes
- Net video, gaming, and virtual worlds.....200 exabytes
- Non-Internet “IPTV” .....100+ exabytes
- Business IP traffic.....100 exabytes
- Other (phone, Web, e-mail, photos, music)...50 exabytes
- Total.....1,000 exabytes = 1 zettabyte

# Zettabyte by 2015



# Data from Bret Swanson & George Gilder,

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s.com](http://www.entropyeconomic<br/>s.com)

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