The Intersection of *Big Data*, *Data Science*, and *The Internet of Things*

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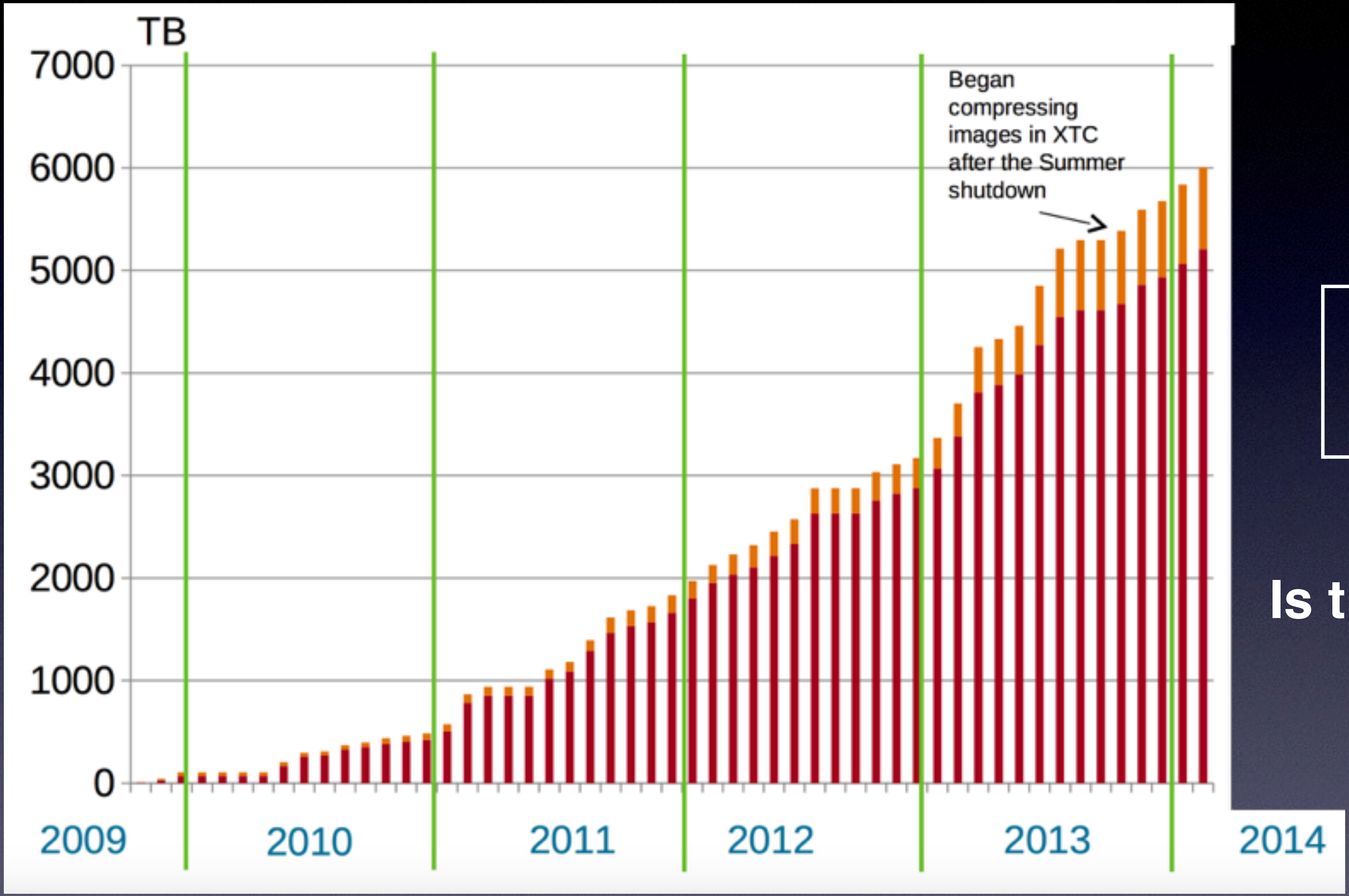
SLAC is a
US national laboratory
operated by Stanford
University

SLAC lives for data and
high performance
computational analysis!

SLAC collects data from a
wide variety of different
devices/sensors

Data from the Linear Coherent Light Source (LCLS)

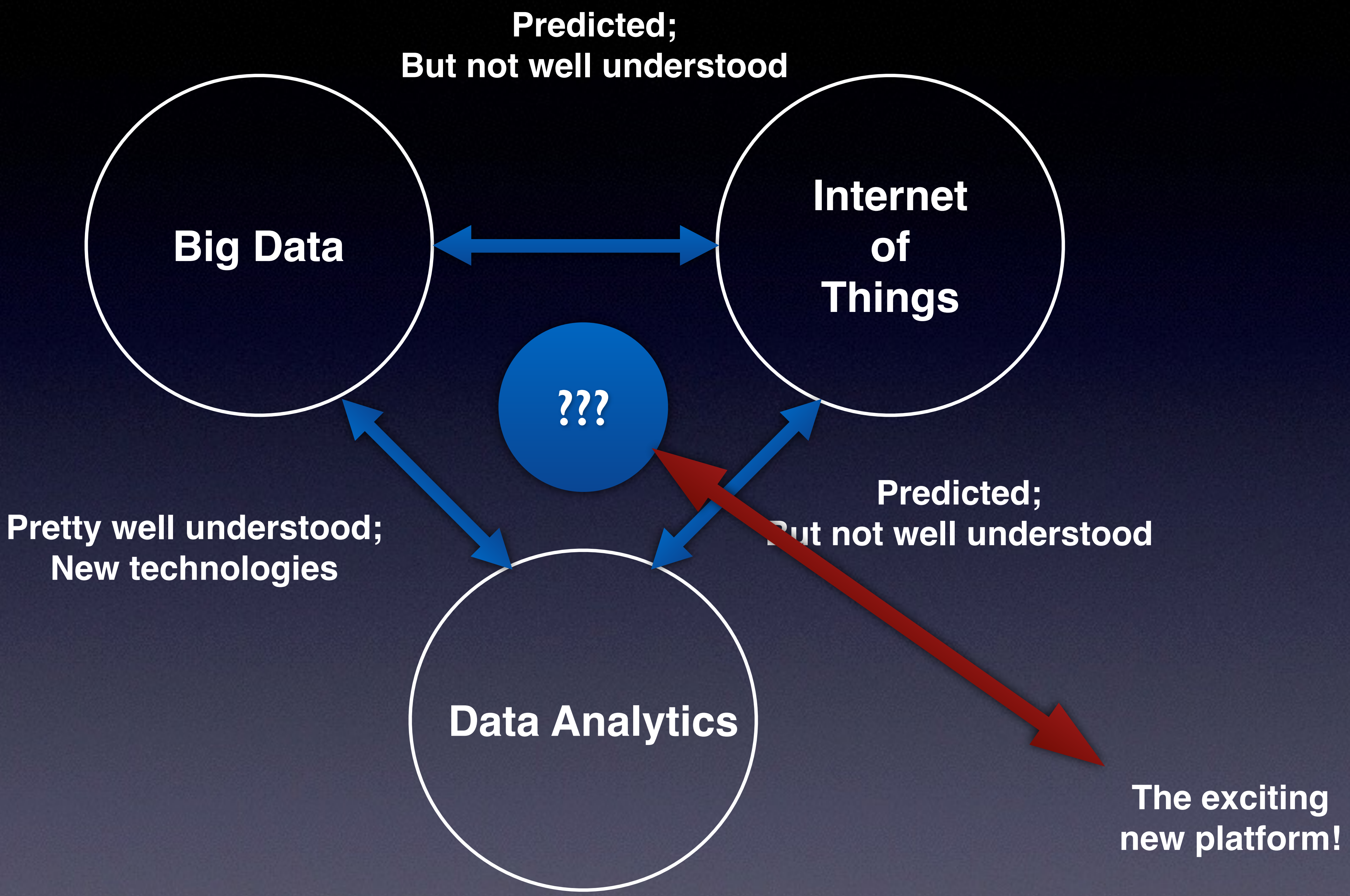


~1.3 million DVDs/month

Is this Big Data?

About My Talk Title

- Have *Big Data*, *Data Science*, and *The Internet Of Things* somehow lost their relevant meaning or are they just buzzwords or hype ?
- How can I possibly put them together in a single talk? - hype^3
- I believe they are all a part of a future convergence



Predicted;
But not well understood

Big Data

Internet
of
Things

???

Pretty well understood;
New technologies

Predicted;
But not well understood

Data Analytics

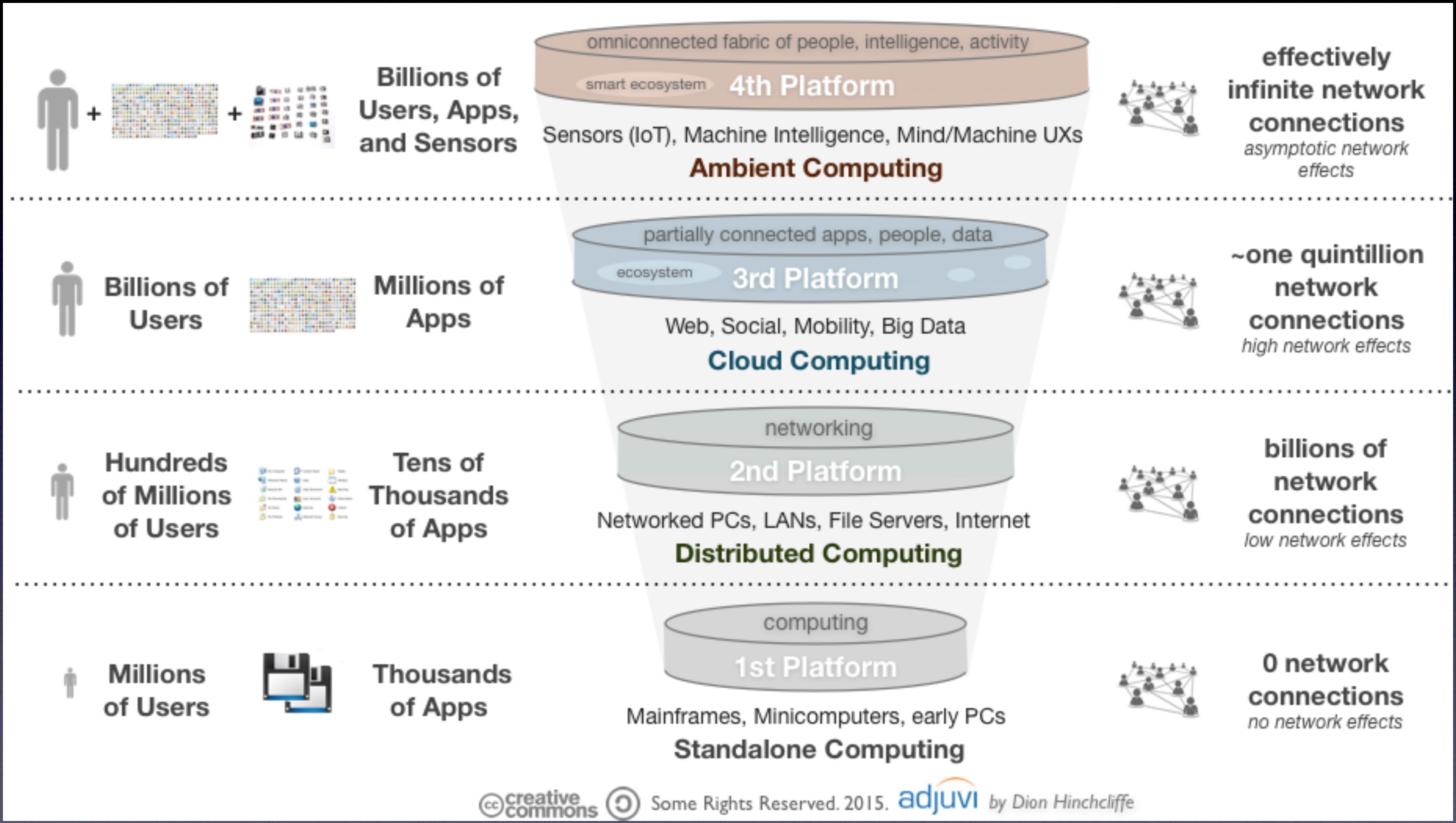
The exciting
new platform!

- Big Data - not new, only matter of scale
- Data Analytics - not new, but grown in complexity to accommodate the “Big Data 4Vs”
- IOT - nothing like it before

- One of the big promises of “Big Data” and “The Internet of Things” is supposed to be ***insight* and *knowledge***

- The key component to bridge the gap between data, insight, and knowledge is ***analytics***

- The key concepts are *platform* and *innovation*



Billions of Users, Apps, and Sensors

omniconnected fabric of people, intelligence, activity

smart ecosystem 4th Platform

Sensors (IoT), Machine Intelligence, Mind/Machine UXs

Ambient Computing

effectively infinite network connections

asymptotic network effects

Billions of Users

Millions of Apps

partially connected apps, people, data

ecosystem 3rd Platform

Web, Social, Mobility, Big Data

Cloud Computing

~one quintillion network connections

high network effects

Hundreds of Millions of Users

Tens of Thousands of Apps

networking

2nd Platform

Networked PCs, LANs, File Servers, Internet

Distributed Computing

billions of network connections

low network effects

Millions of Users

Thousands of Apps

computing

1st Platform

Mainframes, Minicomputers, early PCs

Standalone Computing

0 network connections

no network effects

Why Platform?

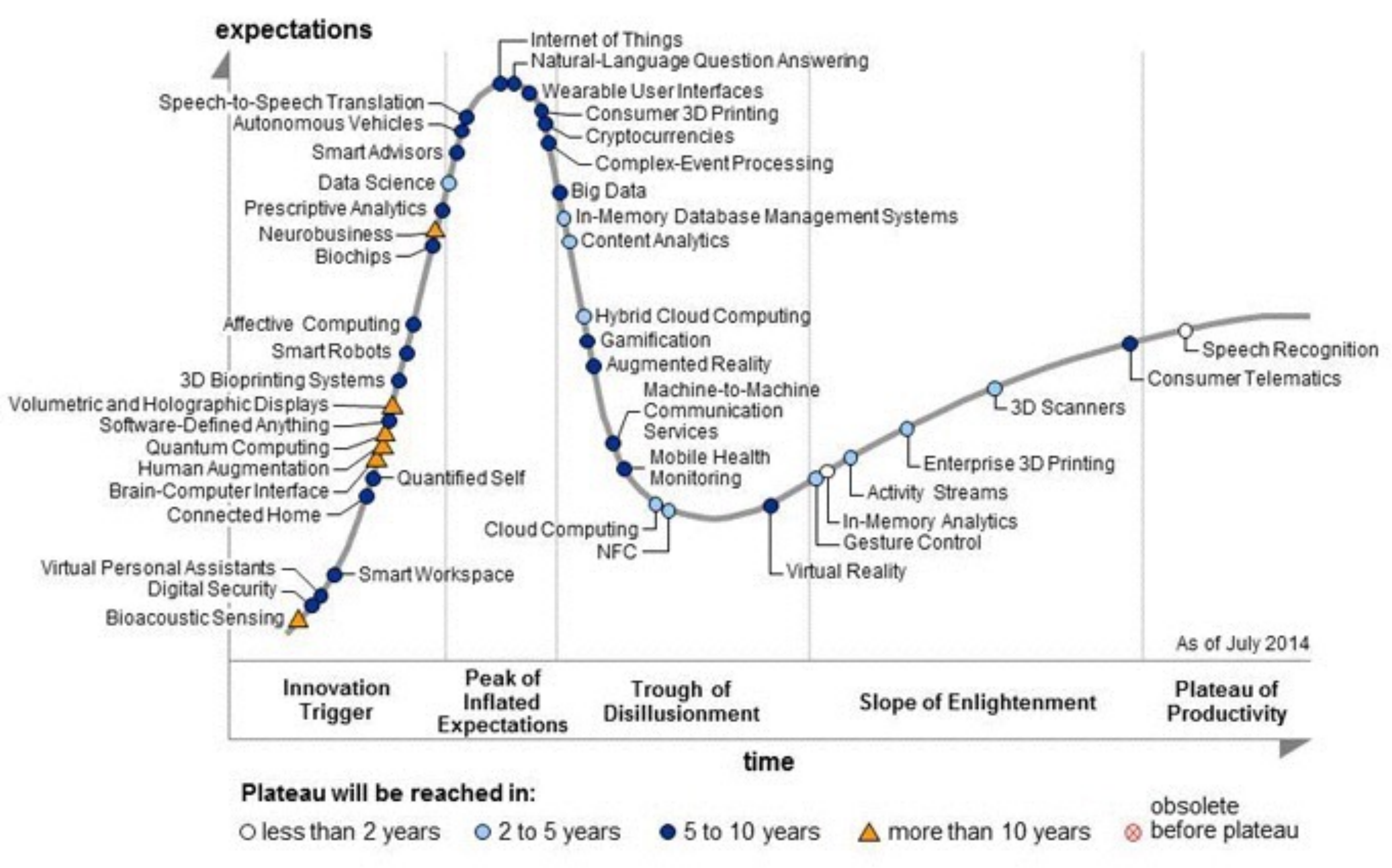
HKU Expert Address, Sept. 2015

4th Platform Critical Elements

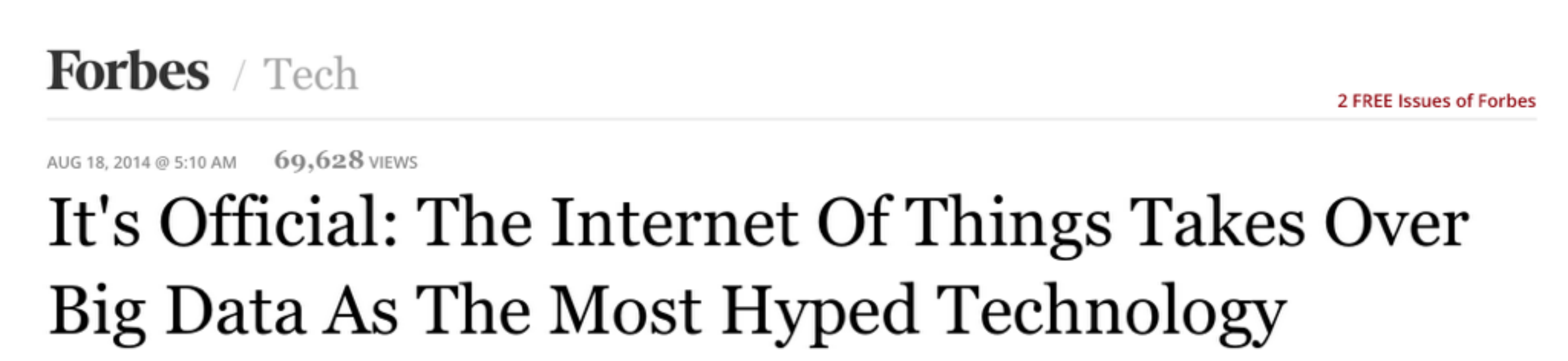
- "Big Data," "The Internet of Things," and "Data Science" are "innovation platforms"
- Infrastructures upon which to build advanced applications
- "Big Data" is maybe too vague (IMHO)
  - Concept has spun off new tools and solutions
  - But usage is perhaps too focused with too many expectations
  - "The Internet of Things" may dwarf "Big Data"

4th Platform Innovation Possibilities

- Dynamic contextual services
- Shared perception and learning
- Ecosystem domination
- Instantly composable apps
- Fully digital business models
- Time augmentation
- Digital communities as institutions



Interesting (to me) that IOT lies midway between Big Data and Data Science



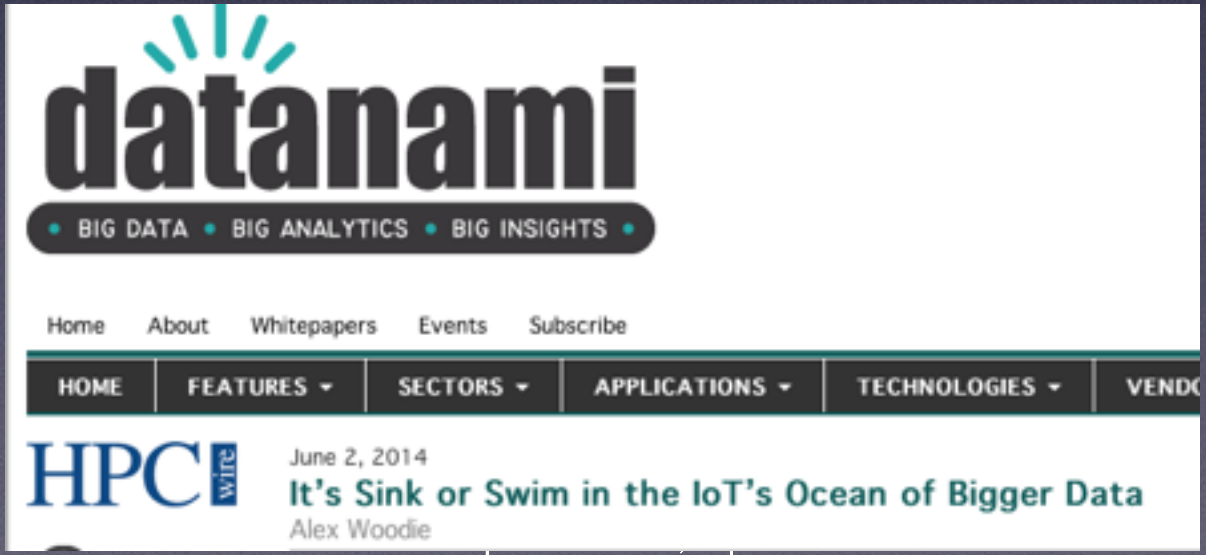
Forbes / Tech

2 FREE Issues of Forbes

AUG 18, 2014 @ 5:10 AM 69,628 VIEWS

It's Official: The Internet Of Things Takes Over Big Data As The Most Hyped Technology

What does this mean?



datanami

• BIG DATA • BIG ANALYTICS • BIG INSIGHTS •

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HPC wire

June 2, 2014

It's Sink or Swim in the IoT's Ocean of Bigger Data

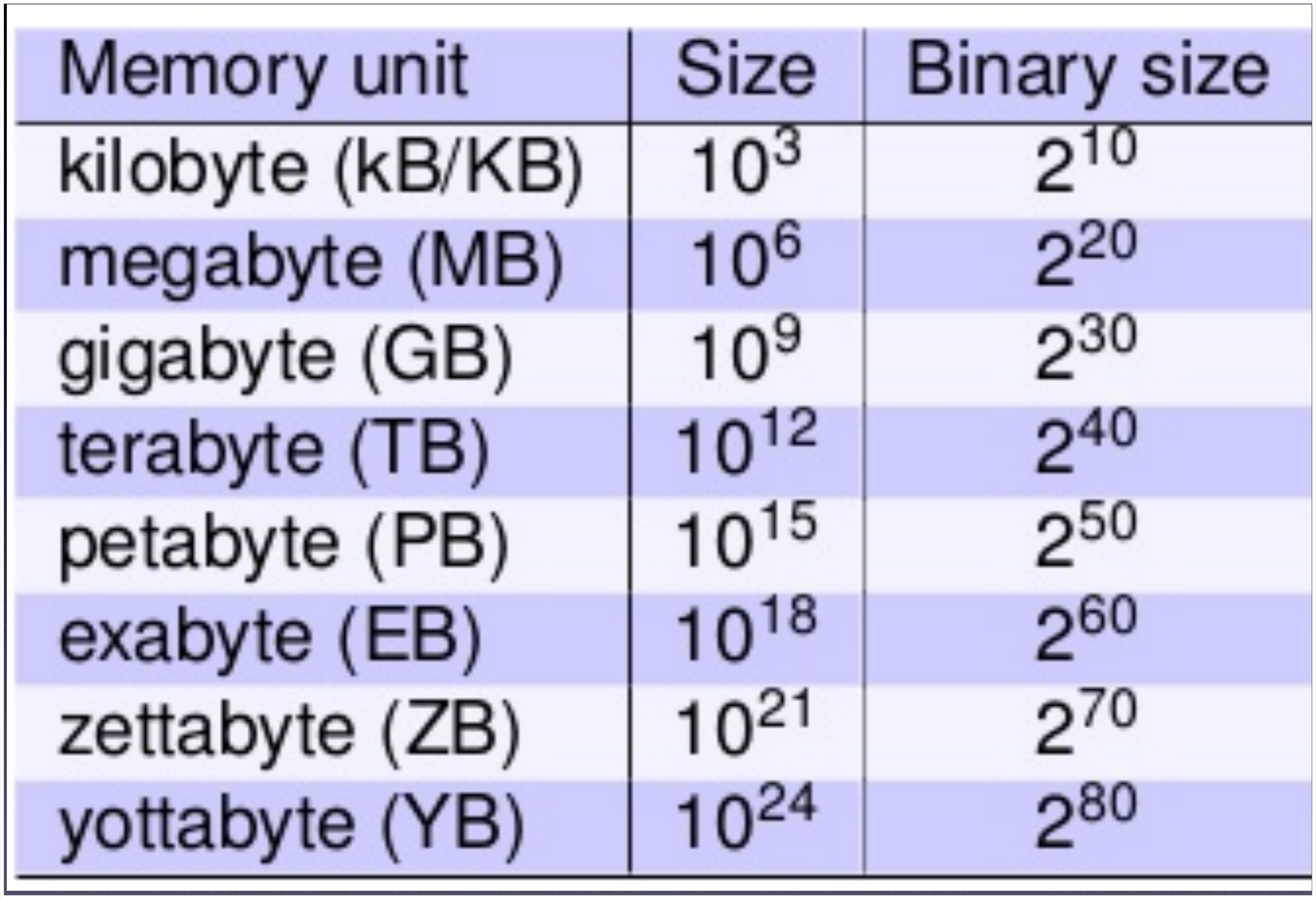
Alex Woodie

But, instead of hype

- Let’s think *evolution* instead of *revolution*
- What do each of these elements individually contribute to a greater whole?

The Data Deluge

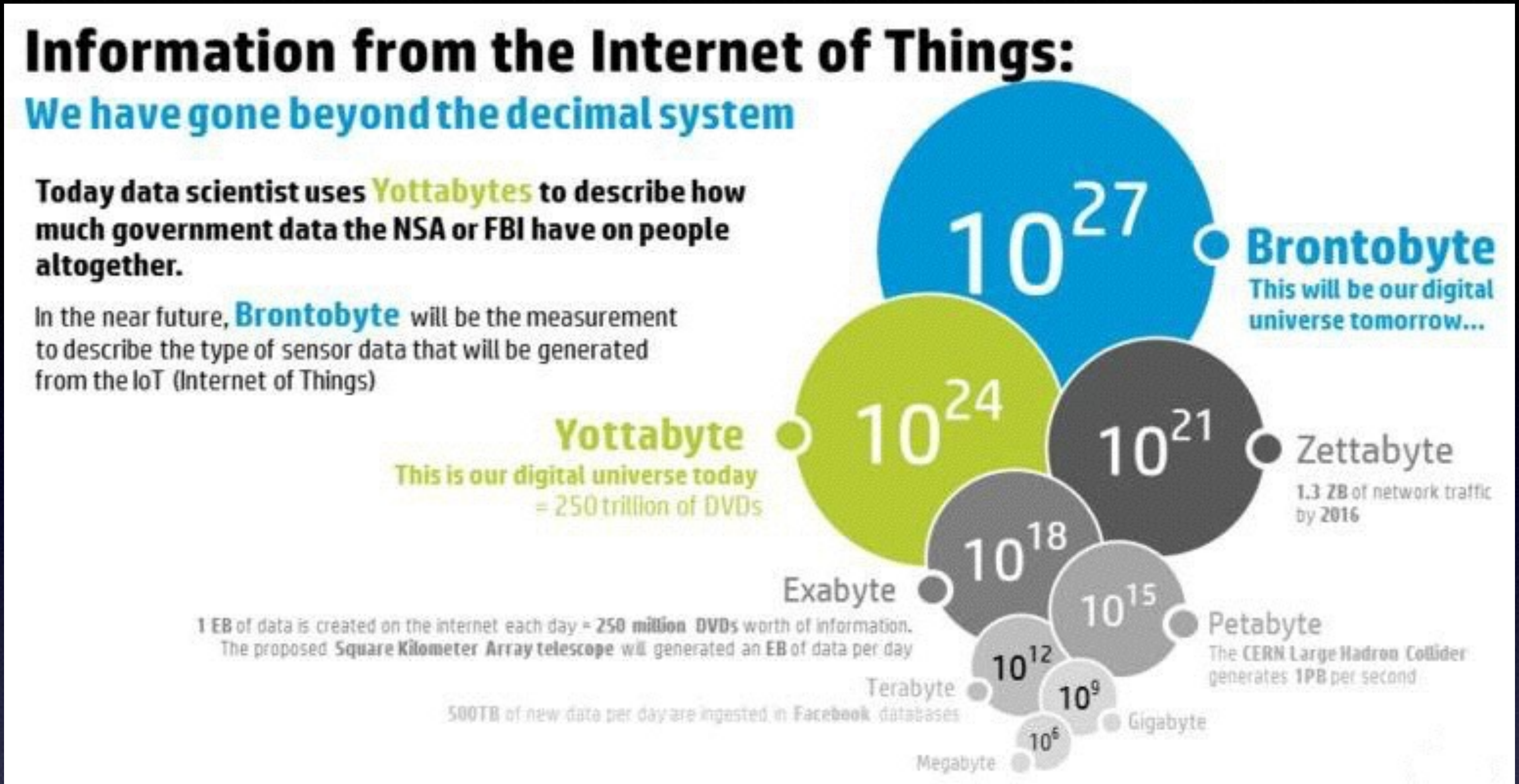
- From the beginning of recorded time until 2003, mankind generated 5 exabytes of data
- In 2011, the same amount of data was generated every two days
- In 2013, the same amount of data was generated every 10 minutes
- In 2015?
- Such numbers become almost meaningless…



Memory unit	Size	Binary size
kilobyte (kB/KB)	10^3	2^{10}
megabyte (MB)	10^6	2^{20}
gigabyte (GB)	10^9	2^{30}
terabyte (TB)	10^{12}	2^{40}
petabyte (PB)	10^{15}	2^{50}
exabyte (EB)	10^{18}	2^{60}
zettabyte (ZB)	10^{21}	2^{70}
yottabyte (YB)	10^{24}	2^{80}

dekabytes?

hectobytes?



Information from the Internet of Things:

We have gone beyond the decimal system

Today data scientist uses Yottabytes to describe how much government data the NSA or FBI have on people altogether.

In the near future, **Brontobyte** will be the measurement to describe the type of sensor data that will be generated from the IoT (Internet of Things)

10^{27} **Brontobyte**
This will be our digital universe tomorrow...

10^{24} **Yottabyte**
This is our digital universe today
= 250 trillion of DVDs

10^{21} Zettabyte
1.3 ZB of network traffic by **2016**

10^{18} Exabyte
1 EB of data is created on the internet each day = **250 million DVDs** worth of information.
The proposed **Square Kilometer Array telescope** will generated an **EB** of data per day

10^{15} Petabyte
The **CERN Large Hadron Collider** generates **1PB** per second

10^{12} Terabyte
500TB of new data per day are ingested in **Facebook** databases

10^{9} Gigabyte

10^{6} Megabyte

10^{25}

A device generating
1 MB/sec starting at the Big Bang

Where is This Data Coming From?

- EVERYWHERE - known and unknown; visible and invisible; with or with permission
- Any communication over a network involves transfer of data that is meaningful to someone
- Every e-mail, every tweet, every transaction, every social media interaction, etc.,etc.
- Sensors - “The Internet of Things”

How is This Data being used (consumed)?

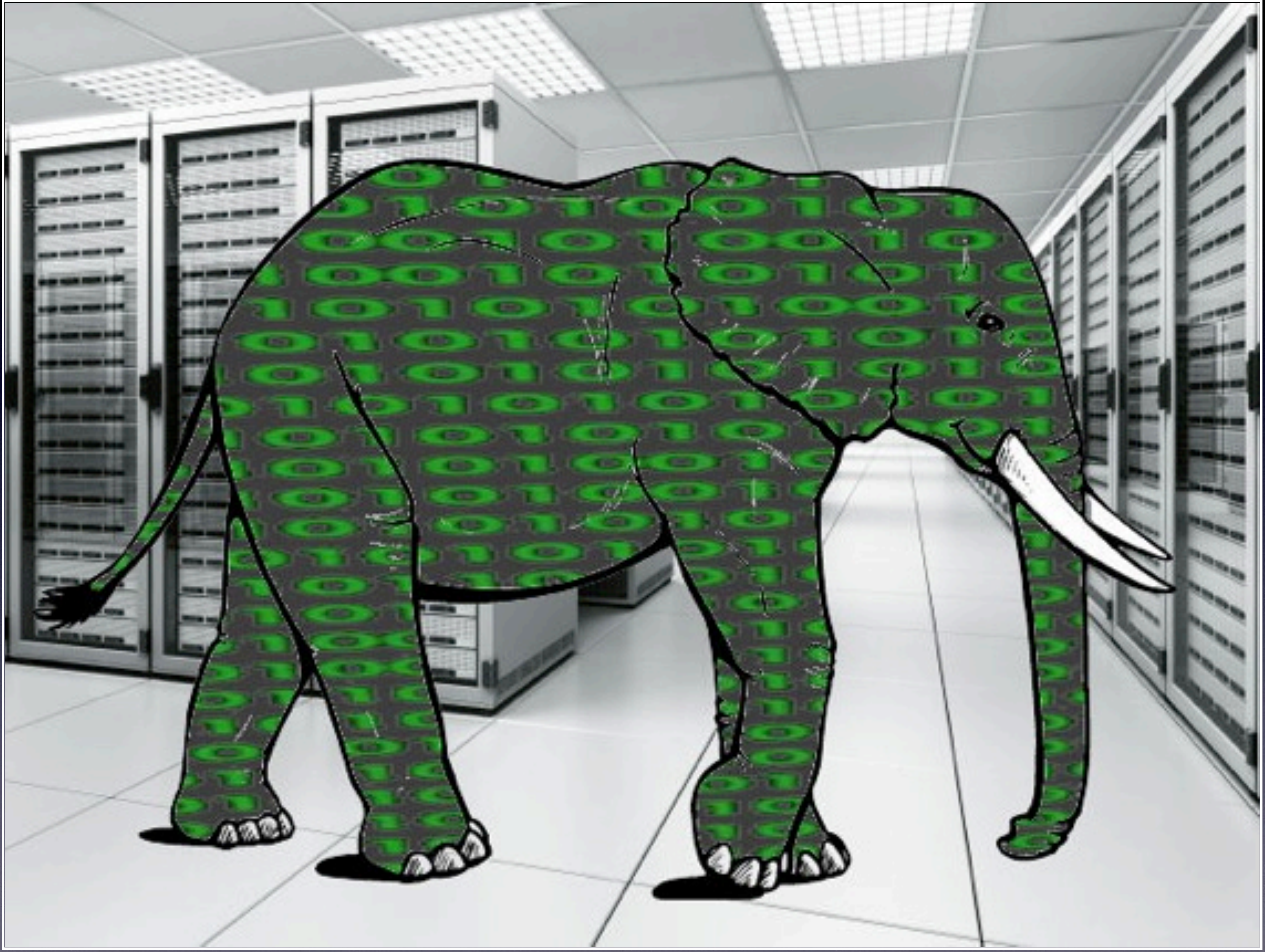
- The “poster children”/“large data generators” for datasets were:
  - Science
  - Finance
  - Government
  - etc.
- Now, we are the experiments creating the datasets
  - Facebook knows what food and music we like
  - Advertisers use cookies and intelligent algorithms to create personalization
  - Amazon even claims to know what we want to (or will) buy next

Big Data - *a Possible Definition*

- Refers to datasets whose size is beyond the ability of
  - Single storage devices
  - Typical database software tools to capture, store, manage, and analyze (McKinsey Global Institute)
- This definition is not defined in terms of data size (which will increase)
- It can vary by sector/usage
- This is not a new issue

Beyond Capability

- 1956 technology
- 5Mb storage
- LCLS would require over 1 trillion units per month



Google processes 20 PB a day (2008)
crawls 20B web pages a day (2012)

JPMorganChase 150 PB on 50k+ servers
running 15k apps (6/2011)

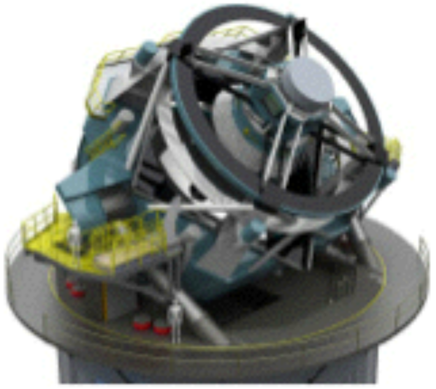
eBay >10 PB data, 75B DB
calls per day (6/2012)

INTERNET ARCHIVE Wayback Machine: 240B web
pages archived, 5 PB (1/2013)

>100 PB of user data +
500 TB/day (8/2012) facebook

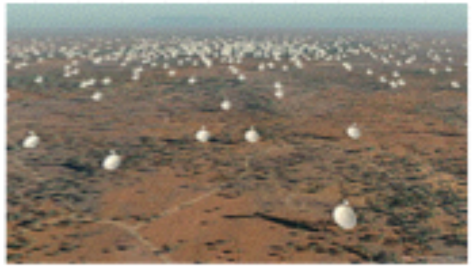
LHC: ~15 PB a year CERN

amazon web services™ S3: 449B objects, peak 290k
request/second (7/2011)
1T objects (6/2012)



LSST: 6-10 PB a year
(~2015)

SKA: 0.3 – 1.5 EB
per year (~2020)



How much data?

The Cloud/IOT is/will be a very “noisy” place

- An unbelievable of objects (theoretically more than 10e38) will be able to talk to us and to each other (orders of magnitude more than now)
- We will be interested in hearing what *some* of them have to say
- How can we manage these conversations?
- Traditional interfaces break down

IOT is the Result of an Amazing Convergence

"We have the capability to fully connect and integrate a wide diversity of devices and objects into the online environment and interact with them"

“The Internet of Things (IOT) includes machine-to-machine (M2M) technology enabled by secure network connectivity and cloud infrastructure, to ***reliably*** transform data into useful information for people, businesses, and institutions”

“The Internet of Things is founded on familiar technologies - like sensors, networking and cloud computing - but its potential for transformation is ***incredible***”

(Verizon)

What is IOT? (to me)

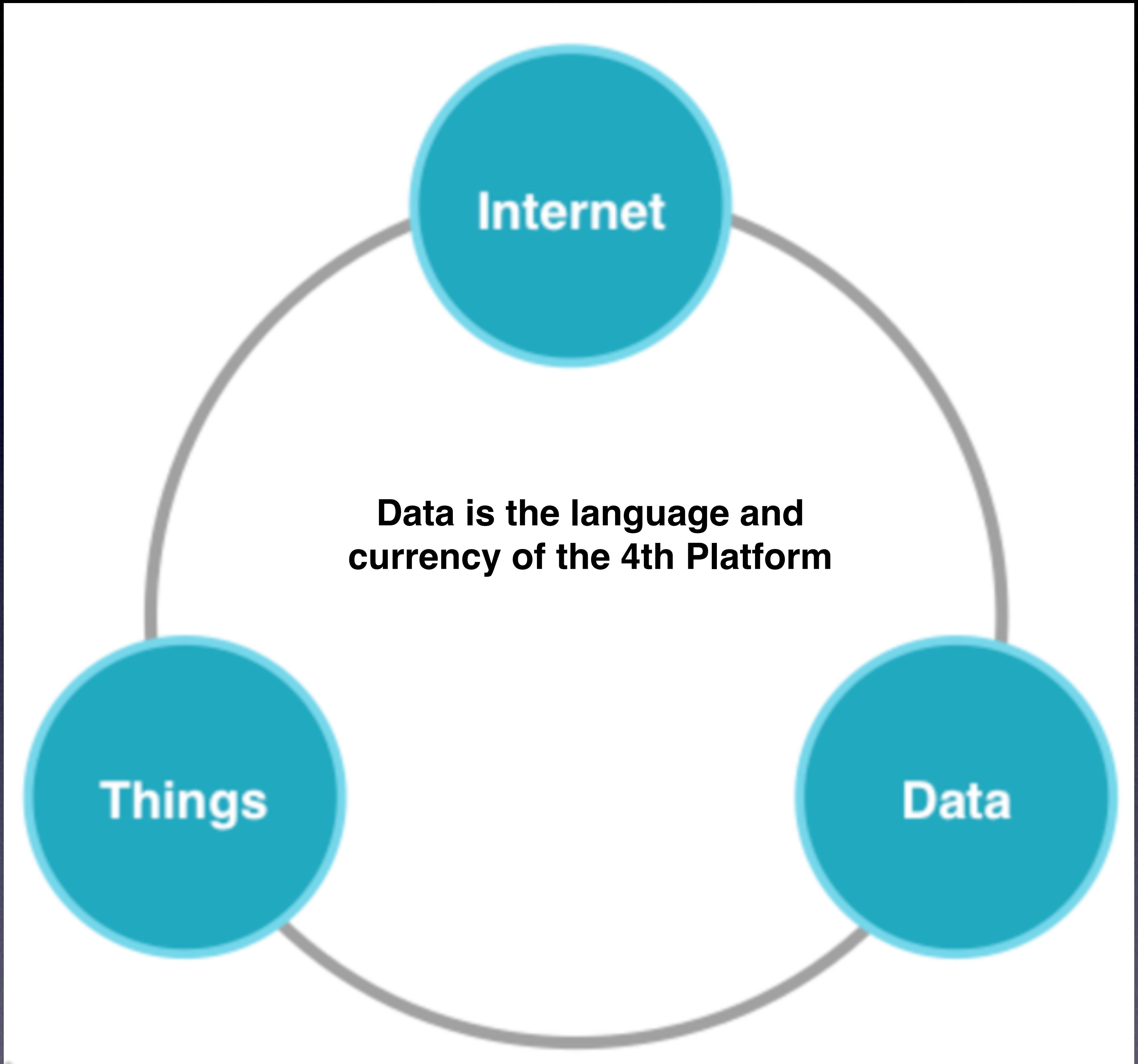
- A communications revolution
- *Communicating* not just copying
- An *interactive* universe of objects, things, data, ideas/concepts and processes both real & virtual
- A *mechanism* to interconnect devices, assets, processes, and systems to improve business models and profits, increase efficiency, and optimize use of resources
- All elements can be integrated & communicate - ***co-dependency***
- A development *platform***

IOT as a *Platform* (1/2)

- A *platform* is an application development environment - beyond the *poster children* - identifying opportunities
- The "Internet platform" resulted in e-mail, WWW, Twitter, etc.,etc.
- The strength of WWW is not just the number of servers or number of pages it has, but what we can do with them (e.g., E-Commerce, E-Learning, E-Government, etc.)

IOT as a *Platform* (2/2)

- The strength of IOT is not just what new (and perhaps bizarre) devices we can add to it
- A “Web of Things” can be built on the IOT
- What will IOT apps look like?; what will they do?
- Will there be a “killer app” for IOT?

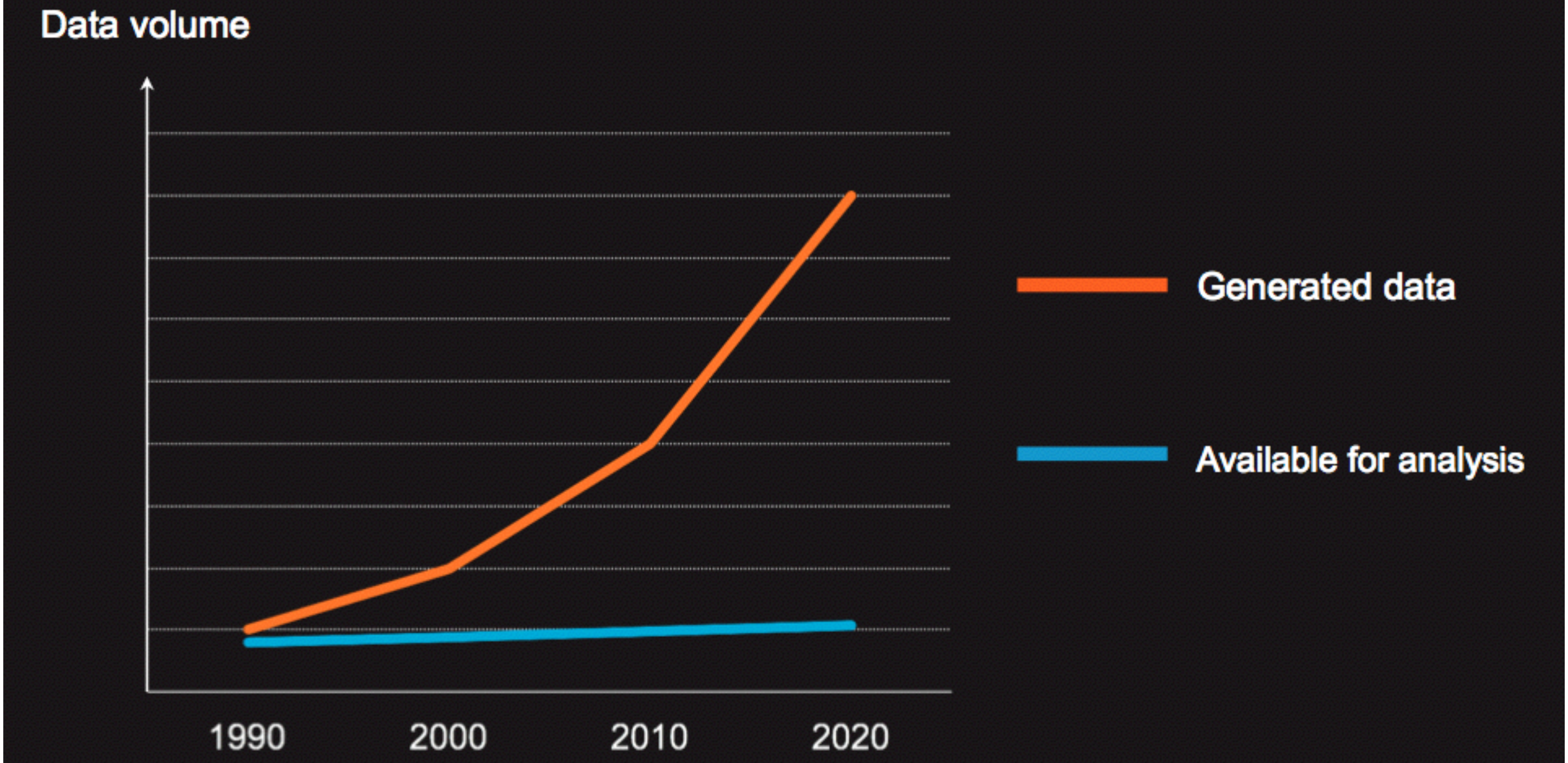


Internet

Data is the language and currency of the 4th Platform

Things

Data



Gartner: User Survey Analysis: Key Trends Shaping the Future of Data Center Infrastructure Through 2011
IDC: Worldwide Business Analytics Software 2012–2016 Forecast and 2011 Vendor Shares

Challenges of Harnessing Big Data

- Not falling for the Big Data hype - why is Big Data better?
- Mining huge datasets; optimizing the signal-to-noise-ratio
- Identifying new analytic techniques and engines
- Shortages of Big Data experts
- Privacy, legal, and social issues
- Addition of the IOT is only going to increase these challenges by orders of magnitude (or not)
- How to avoid "information overload"

Data Analytics and Data Science

- "…[data] analytics is the process of obtaining optimal or realistic decision(s) based on existing data" (Wikipedia)
- "[data analytics is]…the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions" (*Competing on Analytics: the New Science of Winning*)
- There is nothing here about dataset size

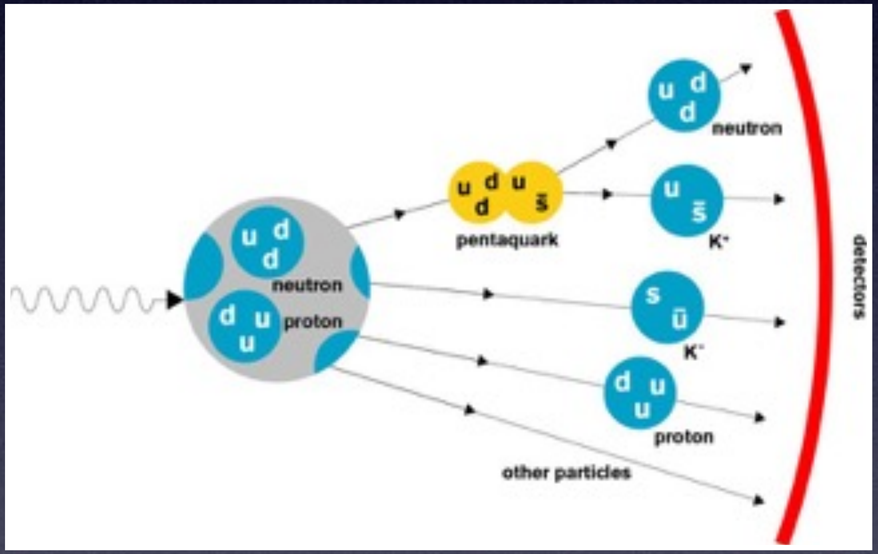
“The theory is that you pump Big Data into the ‘black box’ of an analytics engine - most likely hidden on some unknown server in the cloud - and you get back a continuous stream of insights”

“When you have large amounts of data your appetite for hypotheses tends to get larger. And if it’s growing faster than the statistical strength of the data, then many of your inferences are likely to be false. They are likely to be ‘white noise.’ We have to have error bars around our predictions.”

-Michael Jordan, UC Berkeley

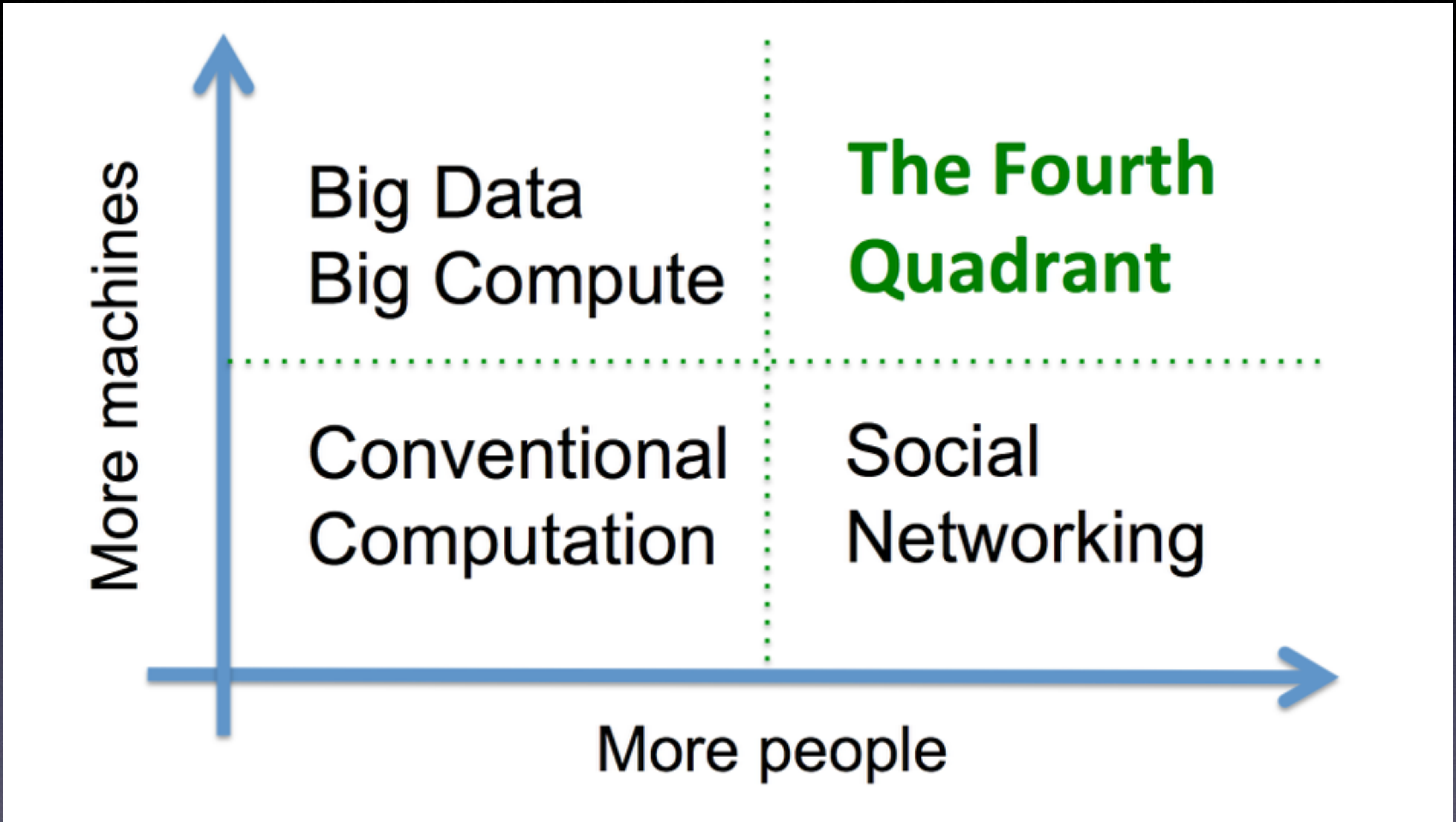
Understand when Big Data is better

- Outliers or small clusters
- Rare discrete values or classes
- Missing values
- Rare events or objects



- With the IOT we will have to learn to *filter* as well as *analyze*

- There will be some communications/data that we do not need to know, collect, or store or could be done at the “thing” level



More machines

Big Data
Big Compute

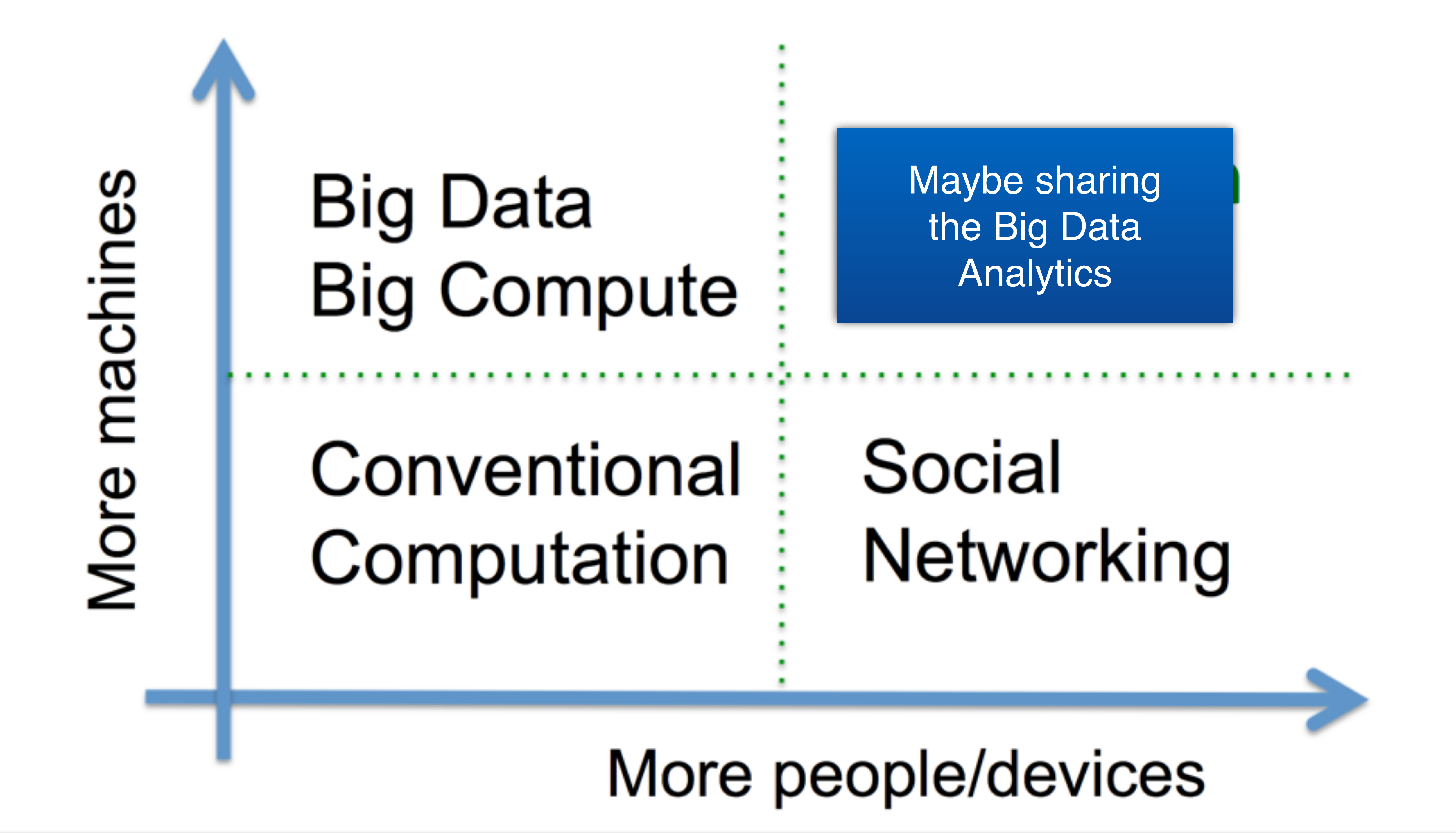
The Fourth
Quadrant

Conventional
Computation

Social
Networking

More people

(From David de Roure)



More machines

Big Data
Big Compute

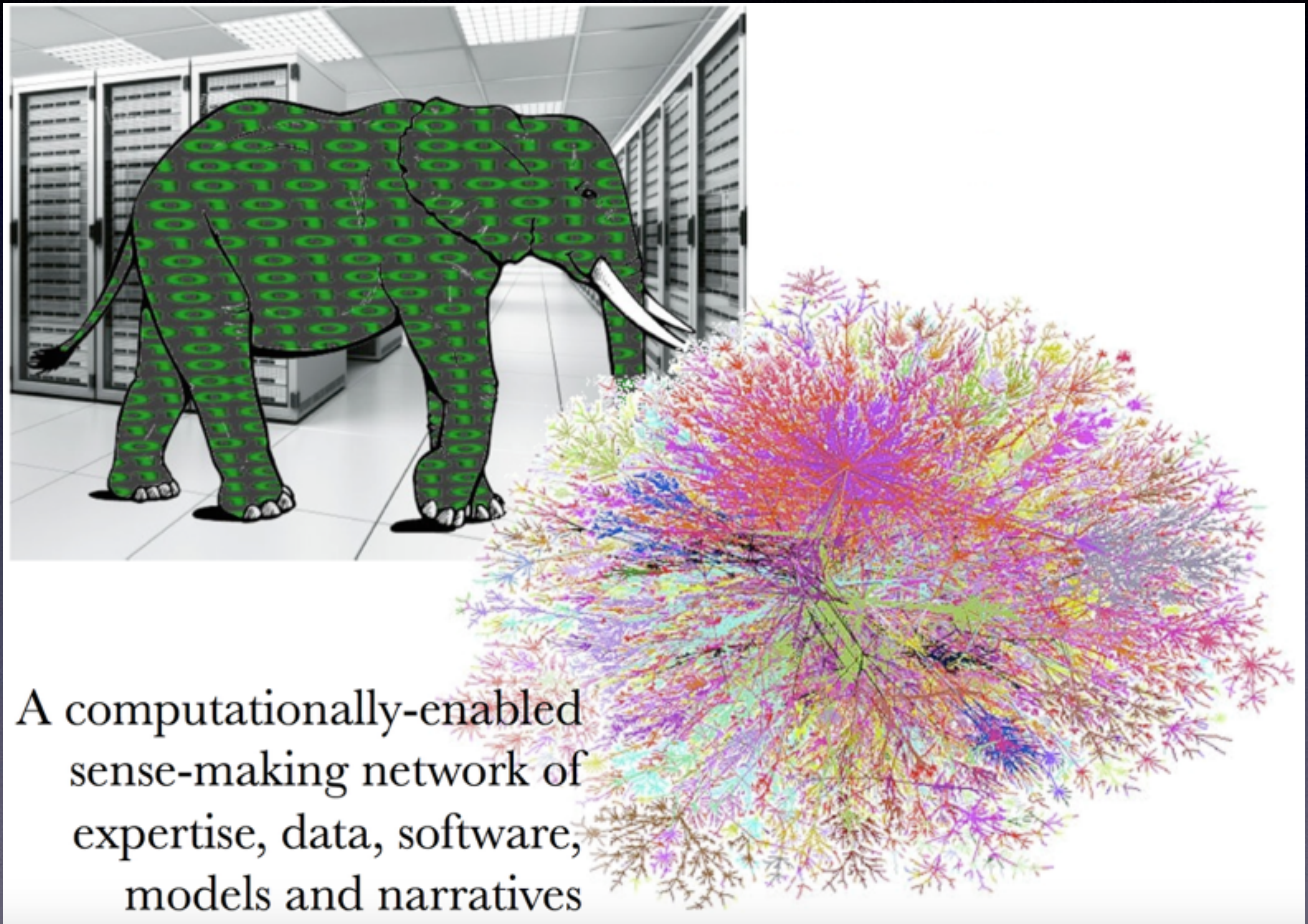
Maybe sharing
the Big Data
Analytics

Conventional
Computation

Social
Networking

More people/devices

The Intersection of “Big Data,” IOT, and Data Analytics



A computationally-enabled sense-making network of expertise, data, software, models and narratives

Today's Takeaways (1/2)

- New forms of data from new data sources will allow us to answer old questions in new ways and to ask and answer entirely new questions
- The future is being driven by a convergence of disruptive technologies
    - Data volume
    - Creative & realtime analytics
    - Computational infrastructure
    - Dataflows vs. datasets
    - Correlation vs. causation
    - Increasing automation
    - Machine2Machine data in the Internet of Things
    - Change in use - not just commercial data mining

Today's Takeaways (2/2)

- The intersection/convergence of Big Data, Data Analytics, and the Internet of Things can lead to "The Fourth Platform"
  - We need to think of the sum rather than just the parts
  - Avoid the hype
  - The potential has only begun to be realized - embrace the platform
  - With the convergence comes big responsibility and unforeseen challenges
- We have an unprecedented opportunity to create knowledge - *Let's Do It!*

Thank You!
Questions? Comments?

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