CS5412/LECTURE 28 THE FUTURE CLOUD

Ken Birman

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OUR LAST LECTURE!

Today, we'll peer into a crystal ball (using lots of web search)

Look at business articles about the future of the cloud, drawing on white papers published in various sources (listed on the syllabus page and in the notes).

THE EVOLUTION OF THE CLOUD AS A MARKET SHAPES THE CLOUD AS A TECHNOLOGY BASE

To understand where the cloud will go in five or ten years, we should try to understand how cloud use and demand will change (or not change).

Investments in new technology concepts and development align with cloud use patterns that scale poorly, and opportunities to increase efficiency.
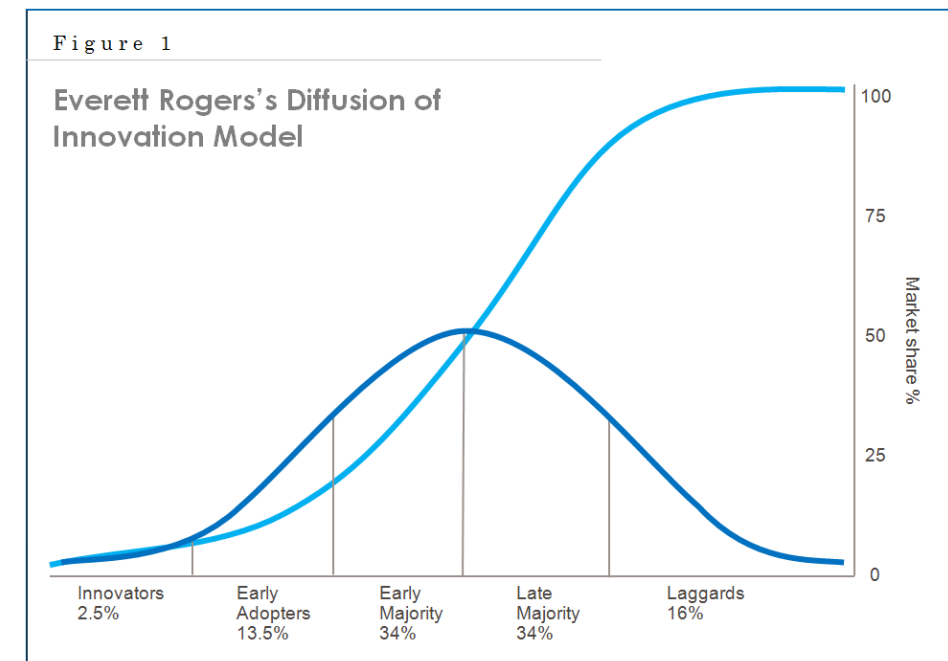
In contrast, things we do well now and will continue to do more of in the future evolve towards greater cost-effectiveness, not new technology.

CURVE SHAPES

We've previously discussed how rapidly-expanding markets are often close to saturating just as they seem to be growing exponentially quickly.

We also discussed the "two peak" adoption curve from Crossing the Chasm

Keep these curves in mind because as we look to the future, both are relevant!

Figure 1

Everett Rogers's Diffusion of Innovation Model

Innovators 2.5% Early Adopters 13.5% Early Majority 34% Late Majority 34% Laggards 16%

CURVE SHAPES

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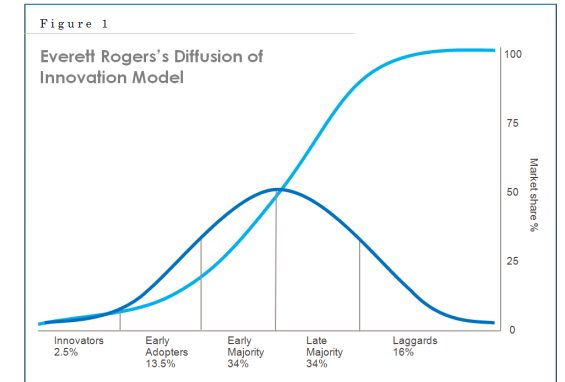Everett Rogers's Diffusion of Innovation Model

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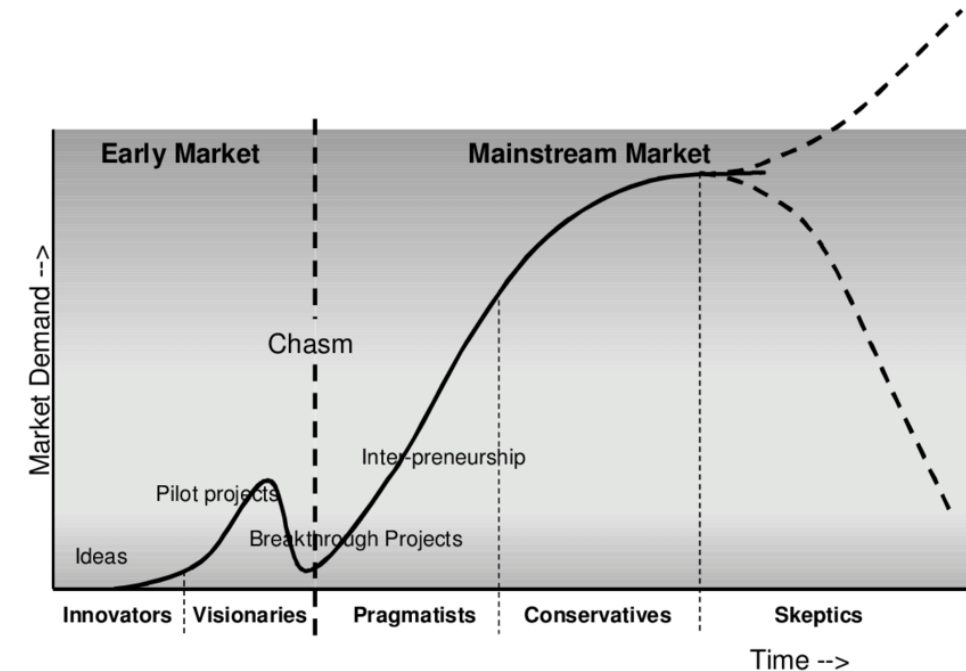Keep these curves in mind because as we look to the future, both are relevant!

CAN WE REALLY PREDICT FUTURE GROWTH?

One idea is to split the question into two sub-questions

For things the cloud does now, what trends are revealed by market research focused on expenditures?

➢ Money is our metric of growth.

➢ This assumes that that what is happening now would more or less continue to happen for a while longer – "probably, no big shakeups".

Things the cloud isn't doing now are different: here we are speculating about new markets, perhaps based on unsatisfied demand.

HOW DO COMPANIES DO PREDICTIONS?

They basically do data mining, or pay someone to do it.

The usual process is to pose a bunch of questions (assumptions) about the market they are excited about. Lots of questions.

Then through interviews with leaders at the top potential clients, they try to learn about the broader trends without limiting themselves to only their favorite clients or their investors. This gives some sense of the picture.

ANALYSIS FOR TODAY: VARIOUS XᴀᴀS MODELS

The cloud is a fusion of many trends and many styles of use.

Today we will try and tease out a few of the interesting sub-trends within this mix.

It isn't so easy because many analysis firms use their own way of understanding the story and identifying niche opportunities for clients

WAIT, WHAT'S WITH THE XₐₐS THING?

In general, "as a service" means "Available for rent on demand. A vendor offers this technology or capability to a large (usually public) clientel."

➤ SaaS: "software as a service". Usually a single application.

➤ PaaS: "platform as a service". These have many separate services in them, like a web platform that can be used to build a sales site.

➤ IaaS is "infrastructure as a service": hardware you can rent

➤ BPaaS: "Business process as a service", like "marketing and sales".

IF AAS WERE USED IN OTHER SETTINGS…

Uber/Lyft do "transportation as a service."

AirBnB does "accommodations as a service."

Cornell does "knowledge as a service."

THEY TALK ABOUT AN "APP MODEL". BUT WHAT MAKES AN "APP"?

The term is a reference to our iPhones and iPads, or Androids: solutions to end-user problems that heavily reuse vendor-provided software tools and infrastructure.

Think about Microsoft Farmbeats: the 2019 version was "home built" and has an IaaS feel. But within a year or two, Farmbeats++ could easily shift towards being more like a collection of Digital Agriculture Apps that share a common Azure IoT Infrastructure. This author is predicting such a shift.

EXAMPLE: PUBLIC REPORTING BY A BUSINESS ANALYSIS FIRM

The report is public because they are hoping to drum up business from readers.

The graphic portrays a progression from "at-home" computing to a larger and more cloud-oriented model.

Cloud-Based Enterprise IT Market 2022 and Beyond
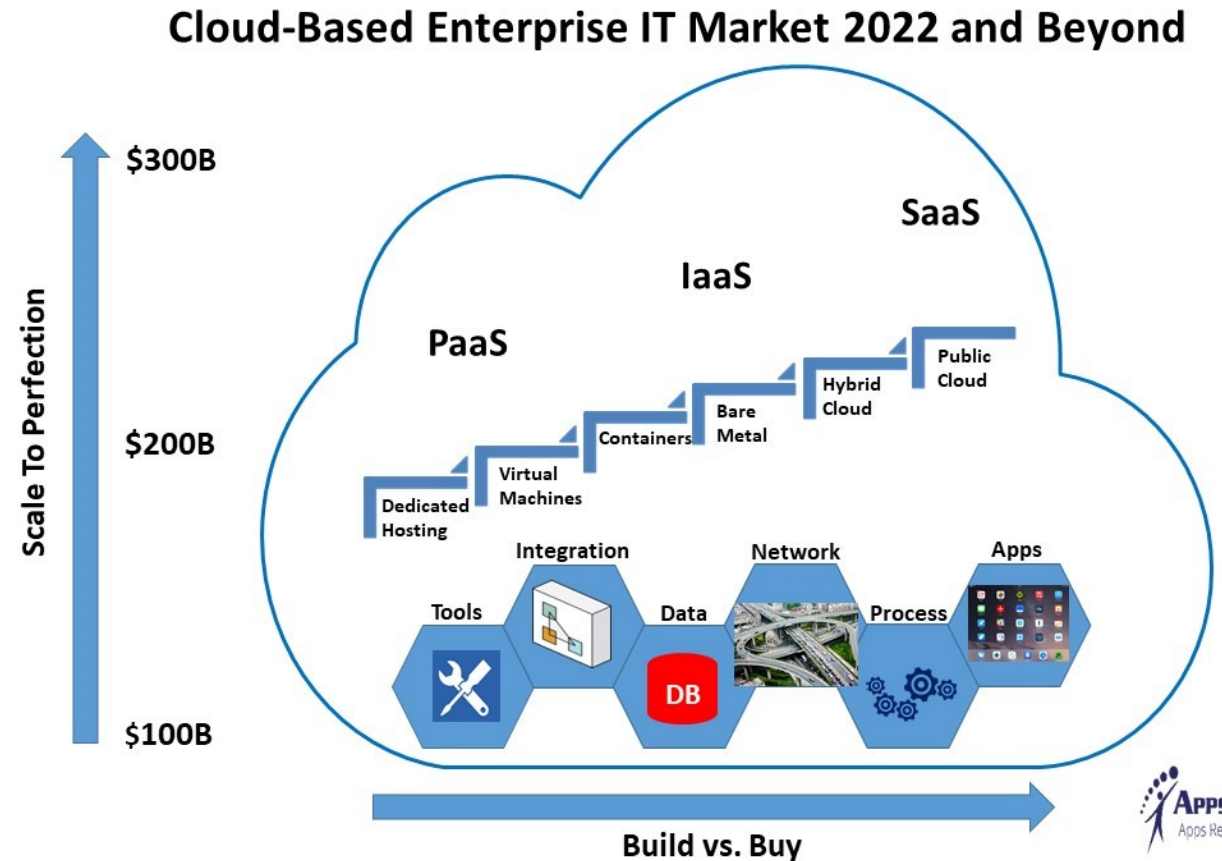
GLOBAL CLOUD MARKET, TOTAL

A "total revenue" picture can obscure important details. When we see a total market estimate, dig deeper!

You can see that Forrester views SaaS as the largest market, by far. But SaaS revenue spreads over many vendors. In contrast, PaaS and BPaaS and IaaS revenue goes to a few "dominant" players

Figure 3 Forecast: Global Public Cloud Market Size, 2011 To 2020

The spreadsheet detailing this forecast is available online.

Total public cloud markets (US$ billions)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BPaaS ($)	0.15	0.23	0.35	0.53	0.80	1.26	1.95	2.93	4.28	6.00	7.66	9.08	10.02
SaaS ($)	5.56	8.09	13.40	21.21	33.09	47.22	63.19	78.43	92.75	105.49	116.39	125.52	132.57
PaaS ($)	0.05	0.12	0.31	0.82	2.08	4.38	7.39	9.80	11.26	11.94	12.15	12.10	11.91
IaaS ($)	0.06	0.24	1.02	2.94	4.99	5.75	5.89	5.82	5.65	5.45	5.23	5.01	4.78

58161

Source: Forrester Research, Inc.

HOW IS THE MARKET EVOLVING?

Notice how platforms or infrastructure models (PaaS, IaaS) are gaining market share, while "bare metal" is fading.

We are moving from renting hardware to renting "solutions"
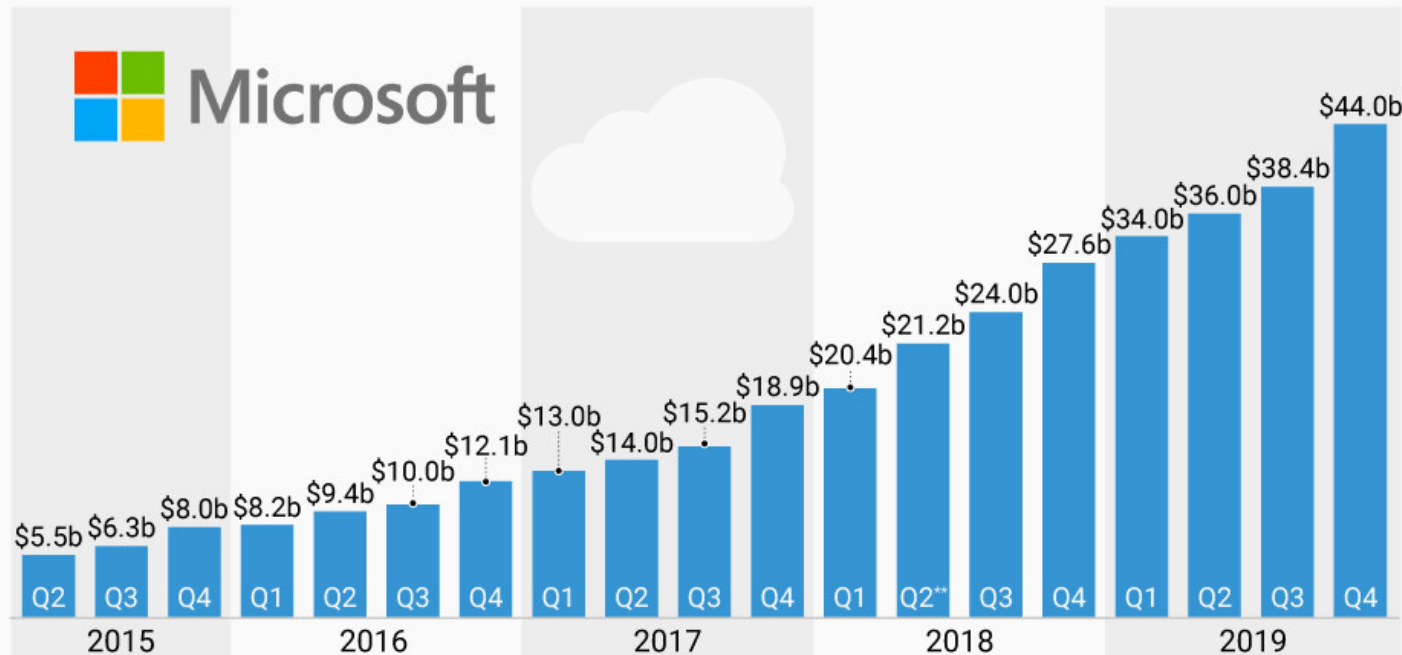
CLOUD COMPUTING 'AS A SERVICE' REVENUE ($B)

21% 2015-2020 CAGR

	2014	2015	2016	2017	2018	2019	2020
PaaS	$2.3	$3.1	$4.0	$4.9	$5.9	$6.9	$8.1
Infrastructure SaaS	$3.1	$4.1	$5.4	$6.8	$8.4	$10.0	$11.6
IaaS	$7.0	$9.7	$12.5	$15.4	$18.2	$21.2	$24.5

https://www.onlineappsdba.com/wp-content/uploads/2018/01/Cloud-Research-revenue.jpg

DIVING IN... MICROSOFT

Microsoft Is Up in the Clouds
Microsoft's annualized commercial cloud revenue run rate (fiscal year ends June 30)*

Quarter	Revenue
Q2 2015	$5.5b
Q3 2015	$6.3b
Q4 2015	$8.0b
Q1 2016	$8.2b
Q2 2016	$9.4b
Q3 2016	$10.0b
Q4 2016	$12.1b
Q1 2017	$13.0b
Q2 2017	$14.0b
Q3 2017	$15.2b
Q4 2017	$18.9b
Q1 2018	$20.4b
Q2 2018**	$21.2b
Q3 2018	$24.0b
Q4 2018	$27.6b
Q1 2019	$34.0b
Q2 2019	$36.0b
Q3 2019	$38.4b
Q4 2019	$44.0b

*Commercial cloud annualized revenue run rate is calculated by multiplying revenue for the last month of the quarter by twelve for Office 365 commercial, Azure, Dynamics 365, and other cloud properties.
**Figures from Q2 2018 onwards were calculated by multiplying revenue for the entire quarter by four.

@StatistaCharts   Source: Microsoft

PC PCMAG.COM   statista

Strong growth, but rate of growth may be tapering off.

One reason for the push into IoT has been to try and find a new revenue driver that could accelerate this growth

But work from home shifted the picture in Q1 2020

DIVING IN... AMAZON

The Blockbuster Growth of Amazon's Cloud Business
Quarterly revenue of Amazon Web Services*

$9.00b

$1.05b

aws

* Amazon Web Services (AWS) is Amazon's cloud platform, providing cloud infrastructure services to start-ups, enterprises and the public sector.

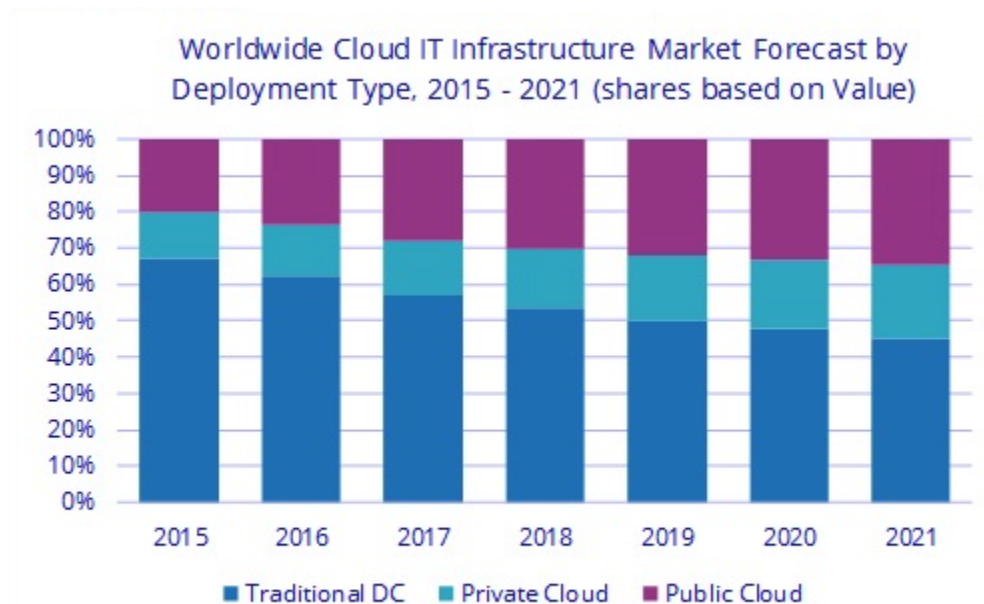@StatistaCharts   Source: Amazon

statista

A big difference is that this chart doesn't include apps.

The one for Microsoft peaked at $44B, but included Office 365 and Teams, which are major revenue generators that use the cloud. Amazon has nothing of that nature in its offering.

MARKET SHARE TREND ANALYSIS

This chart from IDC shows that there is a noticeable shift from traditional owned data centers towards public clouds (AWS, Azure)

With Office 365, one explanation is that companies are shifting their in-house business tasks into cloud SaaS
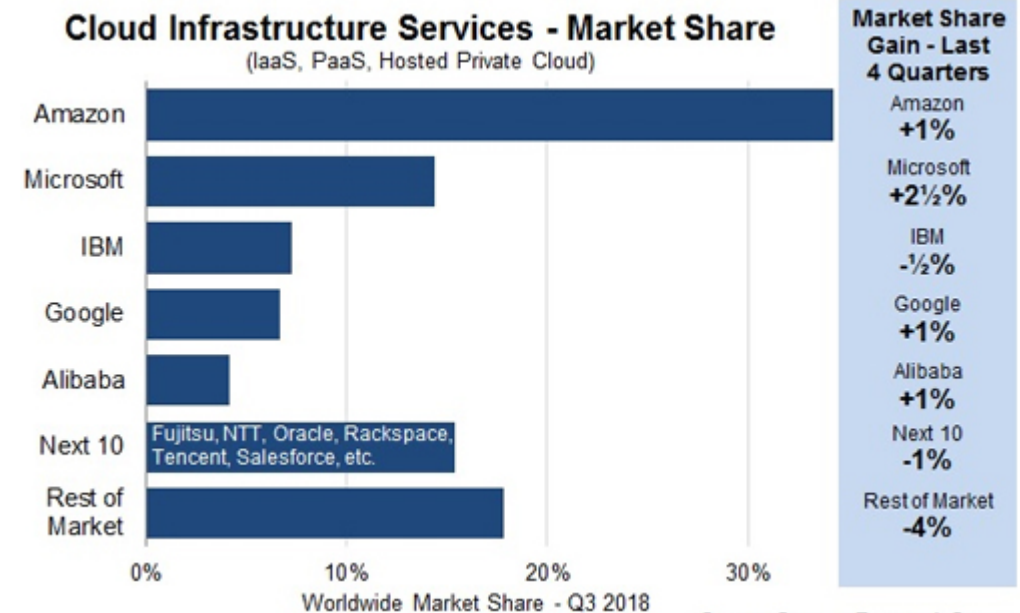
Worldwide Cloud IT Infrastructure Market Forecast by Deployment Type, 2015 - 2021 (shares based on Value)

■ Traditional DC   ■ Private Cloud   ■ Public Cloud

Source: IDC 2018

SLICED IN DIFFERENT WAYS, YOU CAN REACH VERY DIFFERENT CONCLUSIONS

This Q3 2018 data from awsinsider.com (a company with an obvious reason to favor AWS) shows AWS strongly ahead of Microsoft and every other vendor.
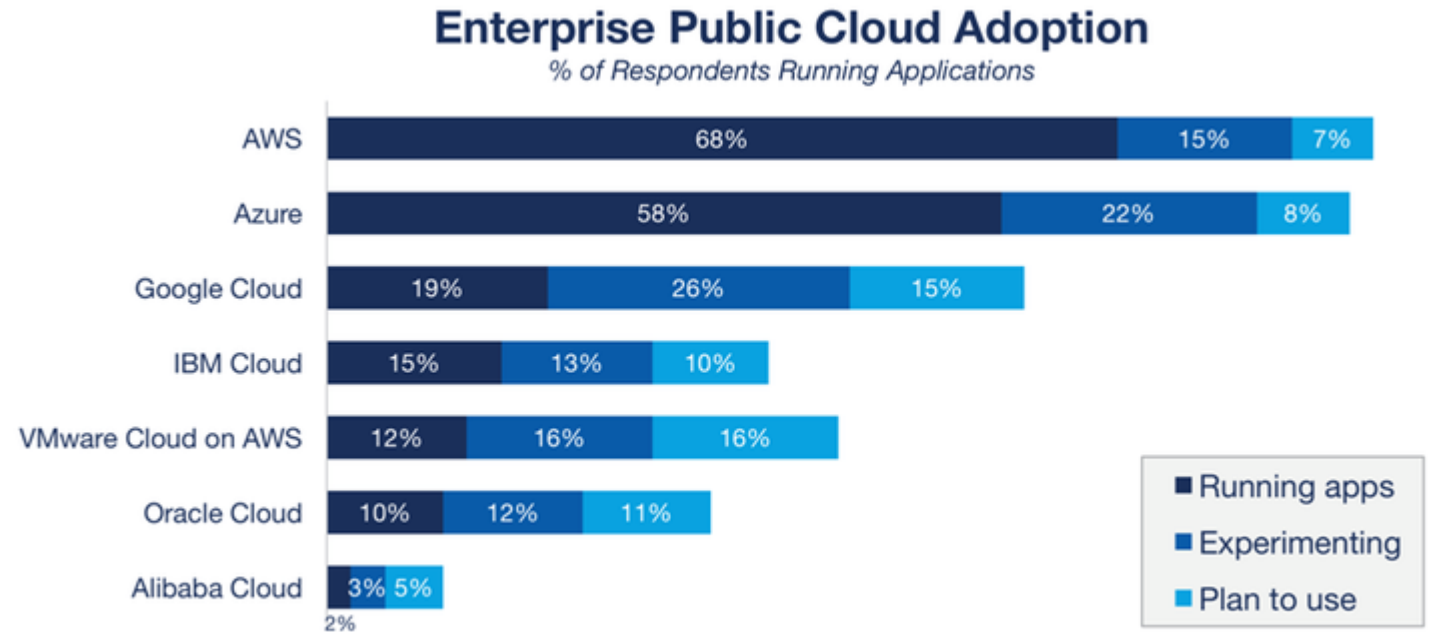
But notice that it doesn't include SaaS, and instead uses a category called "hosted private cloud". What is that?

Cloud Infrastructure Services - Market Share
(IaaS, PaaS, Hosted Private Cloud)

Amazon
Microsoft
IBM
Google
Alibaba
Next 10   Fujitsu, NTT, Oracle, Rackspace, Tencent, Salesforce, etc.
Rest of Market

0%   10%   20%   30%
Worldwide Market Share - Q3 2018

Market Share Gain - Last 4 Quarters
Amazon +1%
Microsoft +2½%
IBM -½%
Google +1%
Alibaba +1%
Next 10 -1%
Rest of Market -4%

MOST "ENTERPRISES" ARE EXPLORING SHIFTS TOWARDS THE CLOUD

This is a market research report from zdnet.com

It shows that Azure and AWS have similar use patterns, but with more experimenting or planning to adopt Azure than AWS
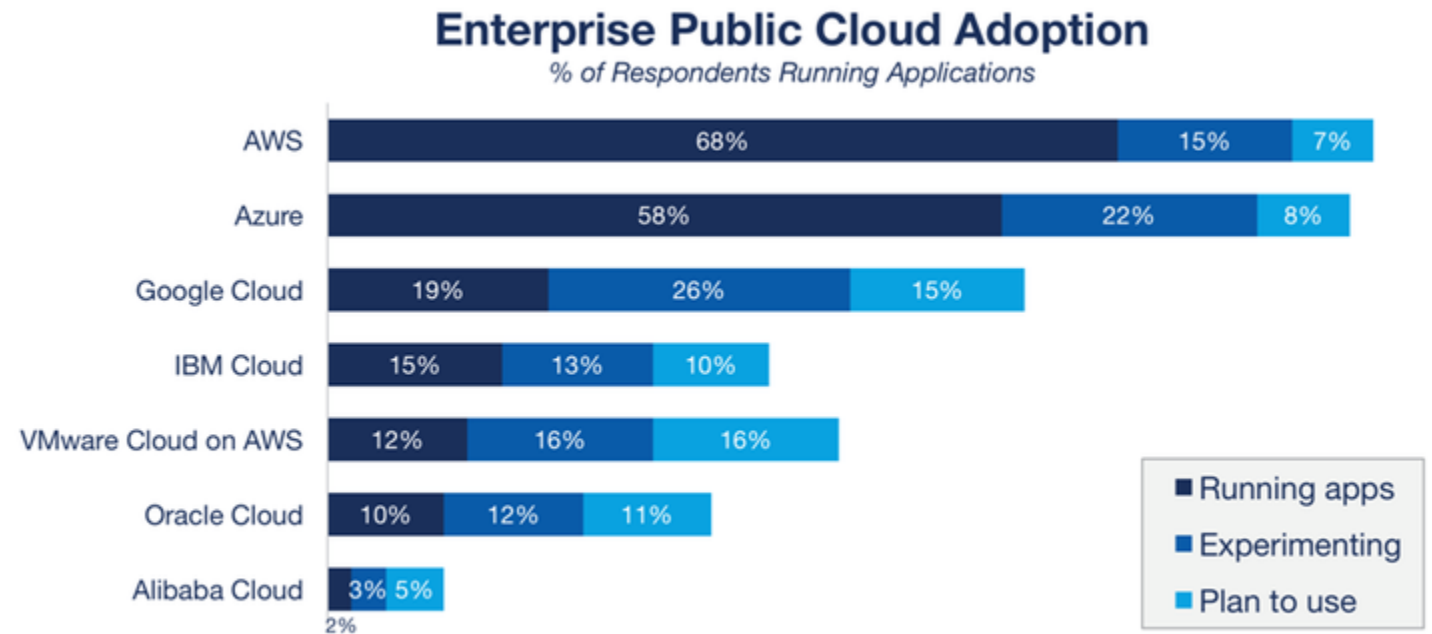

Enterprise Public Cloud Adoption
% of Respondents Running Applications

	Running apps	Experimenting	Plan to use
AWS	68%	15%	7%
Azure	58%	22%	8%
Google Cloud	19%	26%	15%
IBM Cloud	15%	13%	10%
VMware Cloud on AWS	12%	16%	16%
Oracle Cloud	10%	12%	11%
Alibaba Cloud	2%	3%	5%

Source: RightScale 2018 State of the Cloud Report

AWS USE IS MORE ORIENTED TOWARDS IAAS

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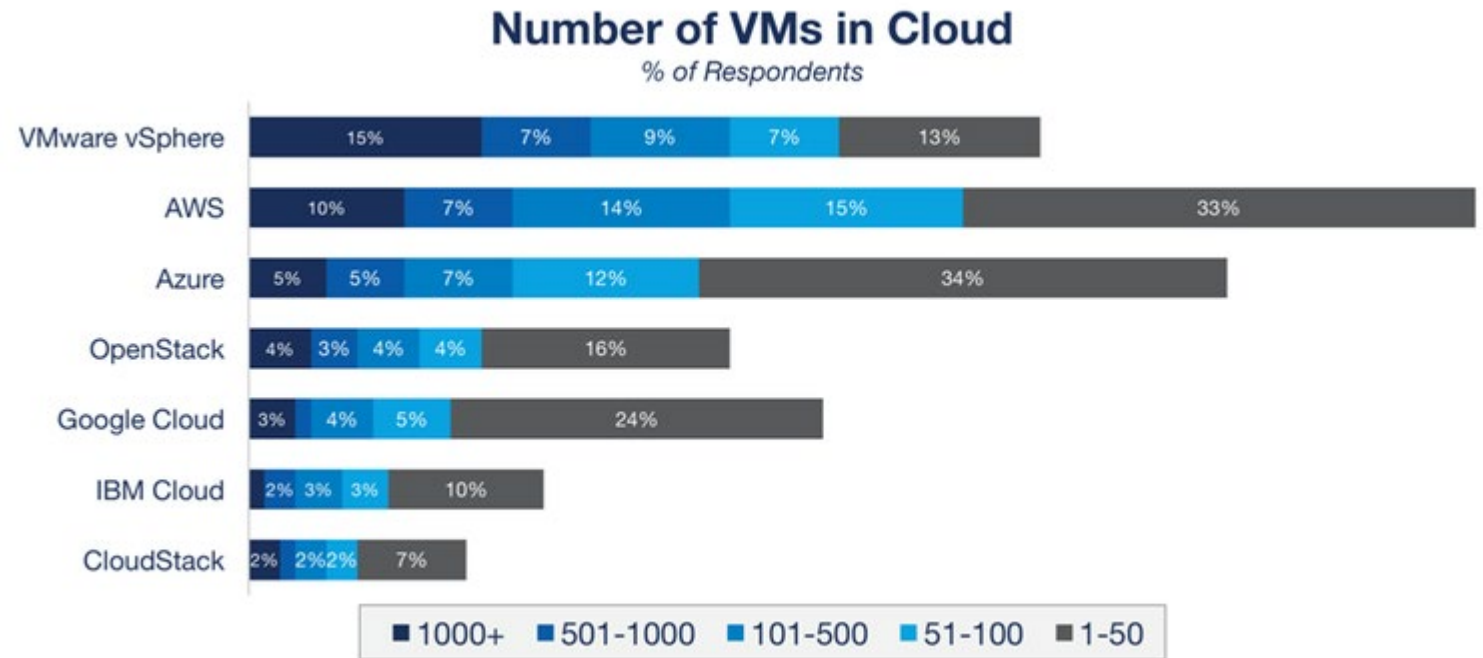
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Alibaba Cloud	3%	5%	2%

Source: RightScale 2018 State of the Cloud Report

MOST "ENTERPRISES" ARE EXPLORING SHIFTS TOWARDS THE CLOUD

If we look just at VMs we are focusing on IaaS rather than SaaS

Here AWS is the clear winner. And more companies are experimenting with AWS too.

Number of VMs in Cloud
% of Respondents

	1000+	501-1000	101-500	51-100	1-50
VMware vSphere	15%	7%	9%	7%	13%
AWS	10%	7%	14%	15%	33%
Azure	5%	5%	7%	12%	34%
OpenStack	4%	3%	4%	4%	16%
Google Cloud	3%		4%	5%	24%
IBM Cloud	2%	3%	3%		10%
CloudStack	2%	2%	2%		7%

Source: RightScale 2018 State of the Cloud Report

AWS GOVERNMENT CLOUD

Hosted Private Cloud means "using AWS infrastructure but not a shared public cloud." The biggest such example is "government cloud"

This is a line of business in which Amazon builds and operates clouds specifically for the US government and military, securely.

That particular line of revenue greatly increases the AWS revenue for cloud as a whole, but in a distinct category.

WHAT ABOUT IoT AS A MARKET?

This chart from "statistica" looks at how many smart devices are out there world-wide

It includes everything from routers and smart TVs to home thermostats that do smart sector control and heat different rooms in different patterns.

Internet of Things - number of connected devices worldwide 2015-2025

Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025 (in billions)

statista
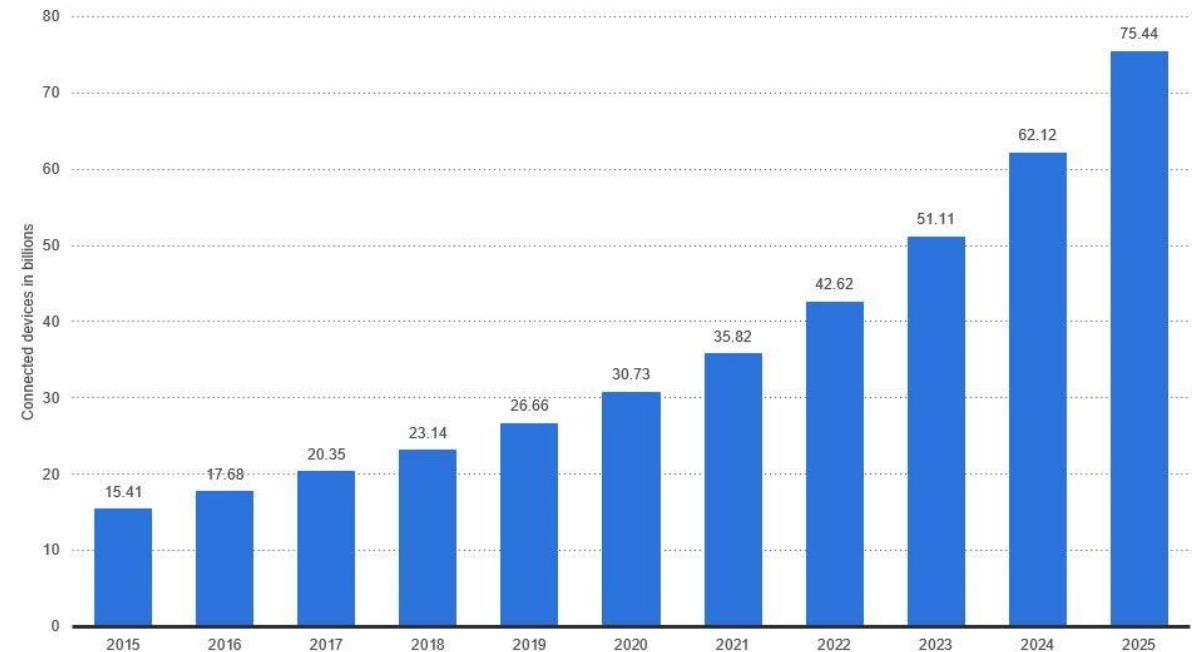
IOT MARKET: SMART GRID

If the power grid of the future will be smart, what will make it smart?

Part of the answer is "it will need to be, to handle distributed energy resources."

Then they point to various specifics that are mostly IoT and cloud, like ML/AI, mobility, cloud computing, data analytics, blockchain!

FIGURE 9

Digital technology capabilities that power companies plan to explore

What digital technology capabilities have you or will you be exploring as part of your digital strategy in the next one to two years? (Select all that apply)

Distributed energy resource management (DERM) solution — 44%

Analytics, artificial intelligence, and machine learning — 42%

Cybersecurity solutions — 38%

Mobile-enabled workforce — 38%

Cloud computing for cross plant/fleet/grid analytics — 35%

A unifying big data platform — 33%

Asset performance management (APM) solution — 32%

Visualization technologies — 32%

Blockchain — 27%

Robotics — 27%

Edge capabilities for on-premise rapid response — 22%

Note: N=81.
Source: Deloitte global Industry 4.0 survey.

Deloitte Insights | deloitte.com/insights

EVERY AREA HAS SIMILAR STORIES!

I happen to work in smart grid, but smart farming is clearly such a story too, and there are smart manufacturing ones, smart cities…

All such stories seem to center on the cloud. IoT is a unifying element because these clouds need to sense the external world and react to new events, or even control things in that external world.

In some ways, IoT is so basic and so obvious that it even goes unstated!

HOW DOES THIS IMPACT OUR TOPIC?

In CS5412 we sometimes look at components and how one uses them.

But we also look deeper and even think about how we could build versions on our own that would work differently and bring new functionality.

An App perspective suggest that "we'll just use standard components."

What technology gap does this expose?

… WE'LL NEED BETTER μ-SERVICE CREATION TOOLS (MAYBE, LIKE DERECHO!)

The tool set for building new μ-services is pretty basic today, like early client-server, where the lack of tools became a major stumbling block.

Azure App Service and the AWS tool for app hosting were both created for web page builders using μ-service models. Those situations have different real-time, consistency and fault models.

An App perspective only makes sense with customized knowledge servers that would need to be supported by an IoT version of the App Service.

SHOULD THIS LACK OF TOOLS WORRY US?

Yes and no!

Yes, because we can think back to early client-server computing days, or the early cloud, when inadequate tools caused the whole industry to stumble and forced major system-wide rebuilds, again and again.

No, because if there is an exciting market, a real one, the money will flow and tools will follow!
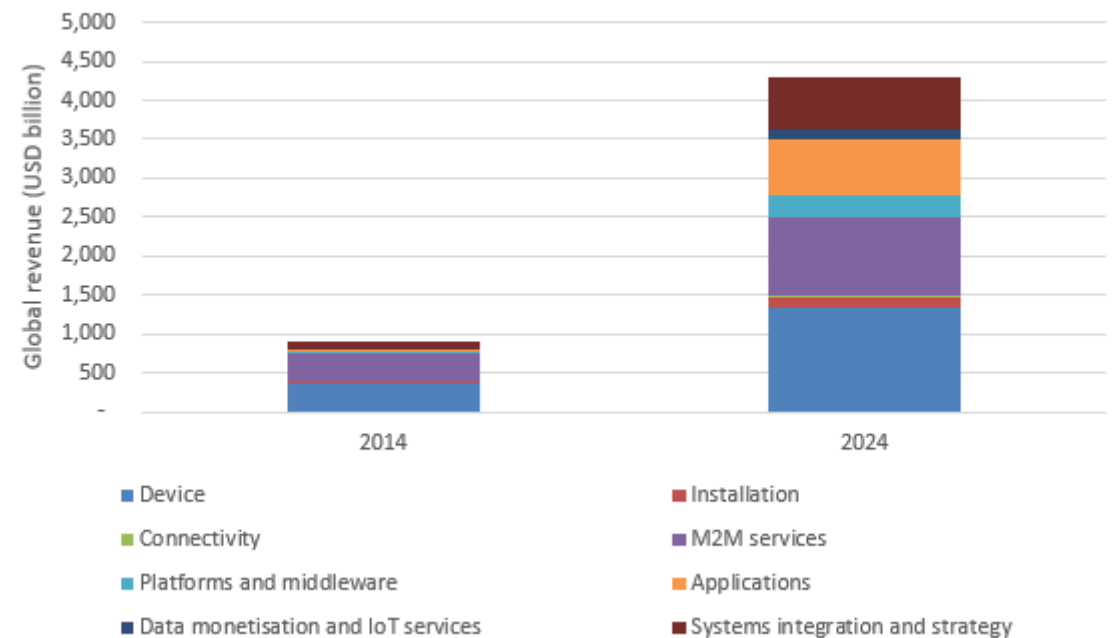
IoT DOLLAR VALUE ESTIMATES (COMPOSITE)

Source: IoT-Analytics.com
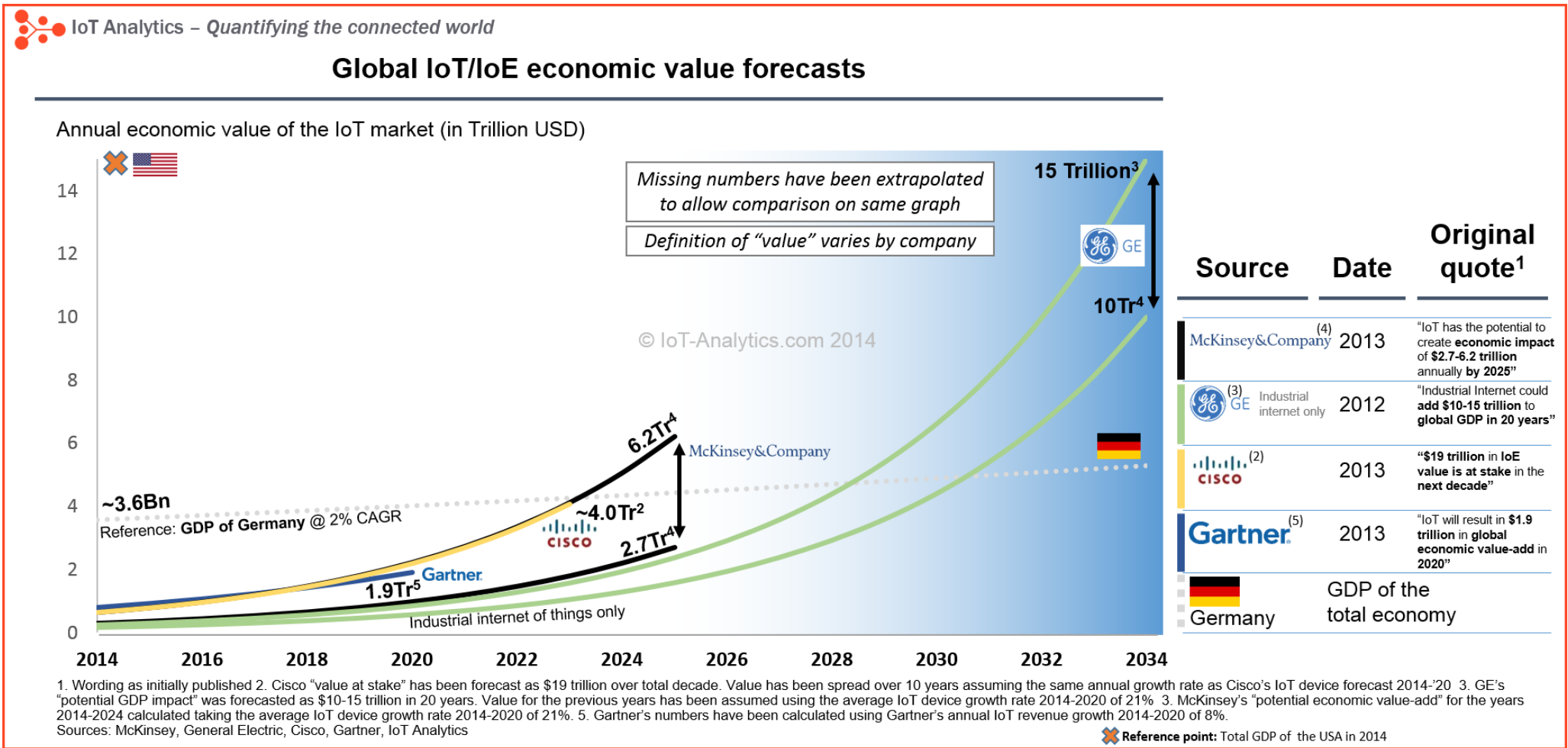
CLOUD SHARE OF IoT MARKET?

This estimate, by Machina Research Inc, suggests that the device dollar value will soon be much smaller than the platform and app value

So this supports the view that Apps could become a very big market for the cloud fairly quickly

Global IoT opportunity, 2014 and 2024 [Source: Machina Research, 2015]

Legend:
- Device
- Installation
- Connectivity
- M2M services
- Platforms and middleware
- Applications
- Data monetisation and IoT services
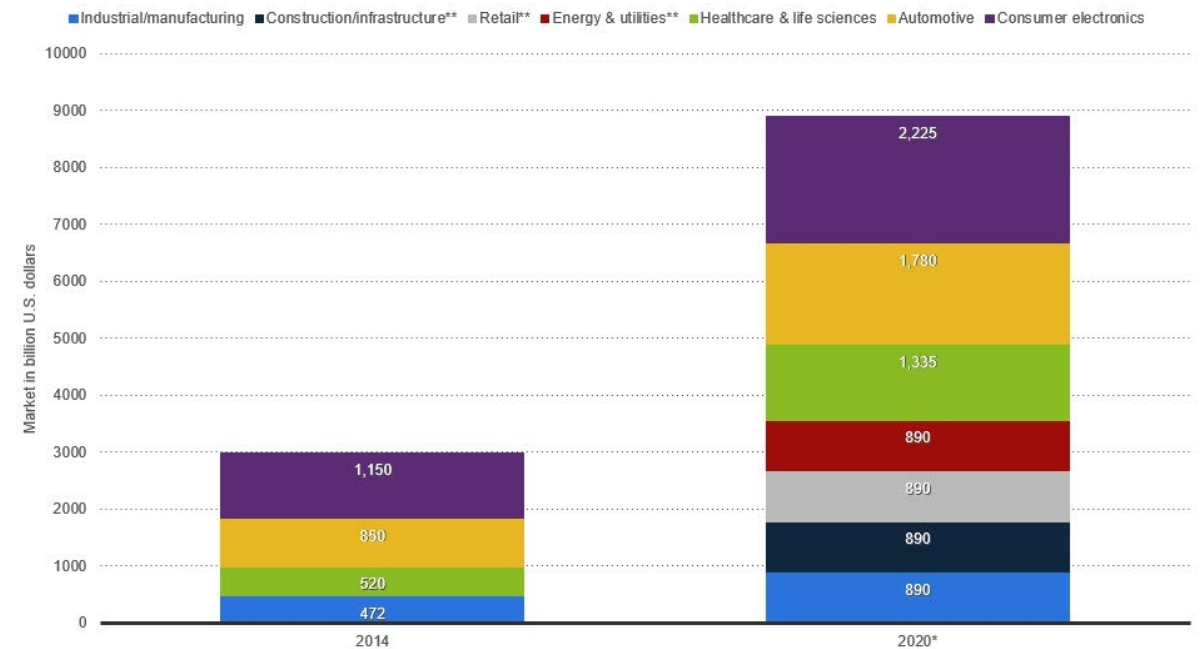- Systems integration and strategy

WHICH INDUSTRIES ARE DOMINANT?

Again, by Statistica.

Strong growth across the board but especially in "non" consumer electronic categories, like automation of retail stores and smart energy systems.

Smart agriculture isn't included here.

Size of the Internet of Things market worldwide in 2014 and 2020, by industry (in billion U.S. dollars)

■ Industrial/manufacturing ■ Construction/infrastructure** ■ Retail** ■ Energy & utilities** ■ Healthcare & life sciences ■ Automotive ■ Consumer electronics

2014	2020*
1,150	2,225
850	1,780
520	1,335
472	890
	890
	890
	890

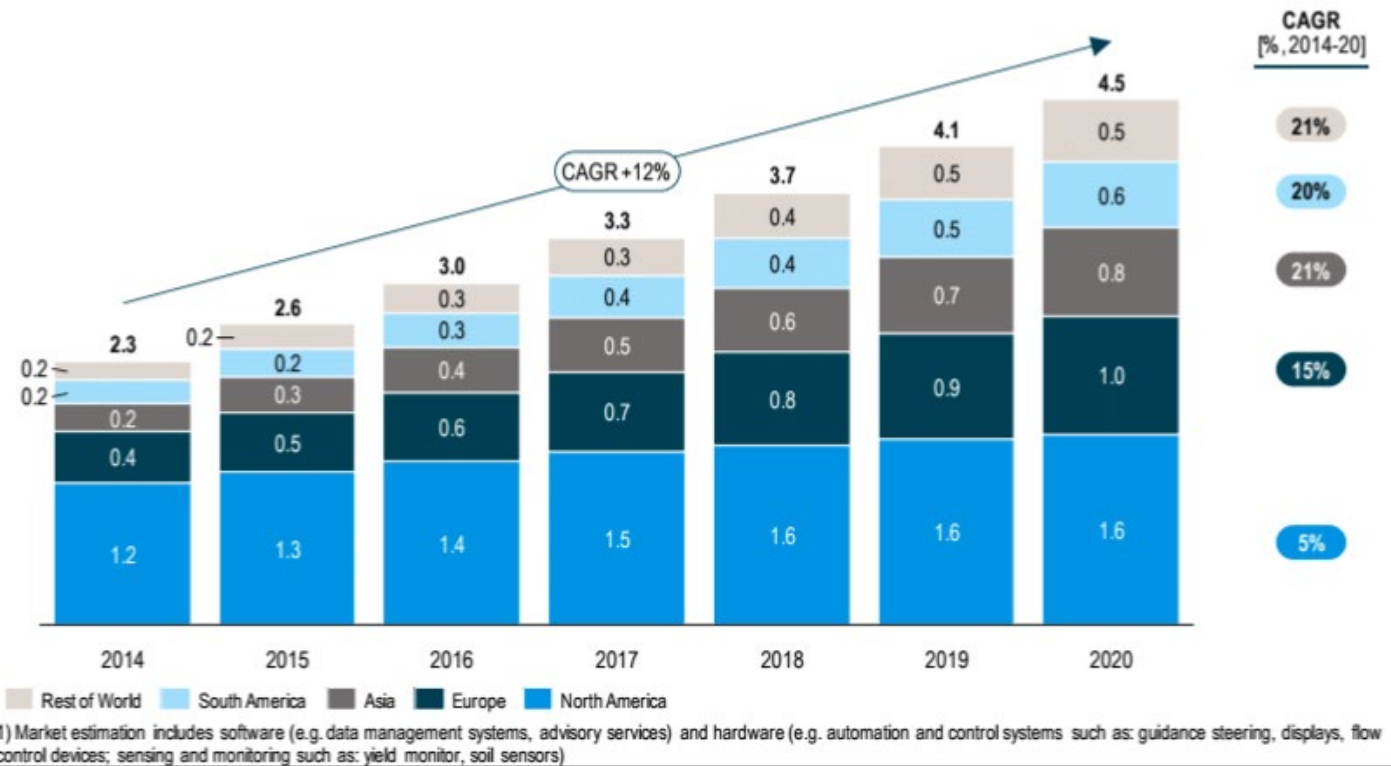Market in billion U.S. dollars

statista

WHAT ABOUT SMART FARMING?

This estimate is by a consultancy called Roland Berger that specializes in farm automation trends.

It supports a view that global growth is strong while US growth is slow.

Figure 2: Market estimation of Precision Farming 2014-2020 [EUR bn]

1) Market estimation includes software (e.g. data management systems, advisory services) and hardware (e.g. automation and control systems such as: guidance steering, displays, flow control devices; sensing and monitoring such as: yield monitor, soil sensors)

Source: Roland Berger

WHAT CAN WE CONCLUDE?

This data generally backs the view that the cloud will become a major player in markets related to IoT during the next five to ten years.

It also supports the view that integrated solutions (SaaS) are growing more rapidly than cloud as a "bare metal hosting VMs" but that there is still huge growth ahead in the IaaS sector.

And it suggests that the main *uses* of IoT are in managed enterprises, not random situations where sensors are just dumped into the environment.

SO HOW CAN WE LEVERAGE THIS INSIGHT?

Back to our focus on actual cloud infrastructure.

It seems to be telling us that the big need isn't going to center on cloud scalability for things the cloud is already doing perfectly well.

➢ On the other hand the sheer scale of the use causes it to be a very high value market, where products that <u>improve efficiency </u>could find uptake.

➢ So on this more mature side of the cloud, expect the emphasis to be on sqeezing more work out of the infrastructure using less money / energy.

MEANWHILE…

On the IoT side, we've spent a semester seeing that the technology base today is just now taking baby steps, but that the opportunity is real.

These predictions suggest that the market may look more like an App market (like Office 365) than like an IaaS market (VMs and hybrid cloud)

So companies that build Apps, or enable people to build Apps, will find strong demand for their solutions (if the solutions are good ones).

APPS FOR THE SMART FARM

https://www.cowmanager.com

As a case in point, think about FarmBeats

As we saw in Ranveer's talk, FarmBeats makes a lot of use of Azure IoT, but many elements seem to be actively evolving.

FarmBeats is not yet an "IoT App" or even an "App ecosystem". Someday it would need to be an App, if the App concept is to be a success.

BIGGEST OPEN QUESTION?

To me, it centers on customized hand-built μ-services, for individual apps (in which case the need for IDEs and other developer tools is the biggest need)

… versus some kind of general purpose "ML as a service" solution, where a precreated vendor-supplied service somehow magically covers all the needed intelligent behaviors.

➤ Such a service could definitely leverage hardware accelerators, a big win

➤ But that same hardware could also be made accessible to custom μ-services through a suitable library, so this isn't a decisive advantage

HOW DOES IT WORK TODAY?

You need to build your μ-service (and it probably is a group of processes, so you need to manage membership, state, handle failures…). Derecho can help on those tasks, if you don't mind coding in C++.

You'll need to register it with Azure or AWS (using JSON files) and then build triggered functions that can talk to it (more JSON files). Some steps are not very intuitive and will require "research" (hours wasted!)

You need to improvise your own debugging and performance analysis tools, and are on your own for long-term "life cycle" aspects.

ASPECTS A PROFESSIONAL SOLUTION WOULD NEED

Clearly, automated help creating those configuration and "task control" JSON files, integrated with AWS Cloud9 or Azure Visual Studio/VSCode.

For the APIs offered to the functions, automation of the API "declarations" and the logic to import them and call them from the function side.

Careful tuning (by the vendor) of the resulting paths. We want our functions running within 1ms or less of an event, and won't have time to launch the container at the last moment, or bind to the service. So those have to be done ahead of time, anticipating the need.

MORE PROFESSIONAL TOOLS WE WILL WANT

Launch service

Authenticate if needed

Register micro/service to accept RPCs

There should be an easy way to create functions able to call the service, using those RPC APIs

We need an efficient upload path for image objects

There will need to be tools for garbage collection (and tools to track space use)

… and tools for managing the collection of configuration parameter files and settings for an entire application

…. and lifecycle tools, for pushing patches and configuration changes in a clean way.

PLUS, SOME LARGER CHALLENGES

Code debugging support for issues missed in development and then arising at runtime

Performance monitoring, hotspot visualization and performance optimization (or even, performance debugging) tools

Ways to enable a trusted micro-service to make use of hardware accelerators like RDMA or FGPA (even if the end user might not be trusted to safely to so)

➢ Many accelerators save money and improve performance but are just not suitable for direct access by hordes of developers with limited skill sets.

➢ Some could destabilize the data center or crash nodes, and some might have security vulnerabilities.

CAN IT BE DONE?

I'm doomed! My boss wants me to lead the μ-service development group!

Actually, no problem!

This is not such a terribly long or frightening list.

The big vendors, like Microsoft and Amazon, can definitely build this sort of technology, and they will do an incredibly good job on it, too.

➢ And they will, if the market is as promising as it looks.

➢ Flow of revenue leads to investment in profitable businesses.

Amazing! My boss wants me to lead the μ-service development group!

CONCLUSIONS?

The cloud infrastructure is an expanding opportunity area!

➢ Using it to create new Apps will fuel many small and big companies

➢ Leveraging the power of the cloud to learn from examples (big data) is an incredible enabler to do things that were impossible with stand-alone code.

Cloud IoT is more of a speculative bet, but looks like a good one.

➢ Even if the cloud just securely manages IoT, this already brings value!

➢ Apps for the IoT edge: maybe a case where 1+1 is way more than 2? E.g., could secured IoT devices plus apps that leverage them take off?