Fog Computing and its Ecosystem

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Abstract

Fog Computing and its Ecosystem

In relation to “cloud computing”, it is bringing the computing & services to the edge of the network. Fog provides data, compute, storage, and application services to end-users. Fog Computing is also known as Edge Computing within the industry. The distinguishing Fog characteristics are its proximity to end-users, its dense geographical distribution, and its support for mobility. Services are hosted at the network edge or even end devices such as set-top-boxes or access points. Thus, it can alleviate issues the IoT (Internet of Things) is expected to produce such as reducing service latency, and improving QoS, resulting in superior user-experience. Fog Computing supports emerging Internet of Everything (IoE) applications that demand real-time/predictable latency (industrial automation, transportation, networks of sensors and actuators). Thanks to its wide geographical distribution the Fog paradigm is well positioned for real time big data and real time analytics. Fog supports densely distributed data collection points, hence adding a fourth axis to the often mentioned Big Data dimensions (volume, variety, and velocity).

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Agenda

- The first wave of Cloud computing
- Challenges of Cloud Computing
- Transitioning from Cloud to IoT & IoE to Fog Computing
- General awareness on IoT, IoE & Fog Computing
- Introducing Fog Computing as an Extension of Cloud
- Comparing & Contrast of Fog and Cloud
- What's Next?
- Q&A

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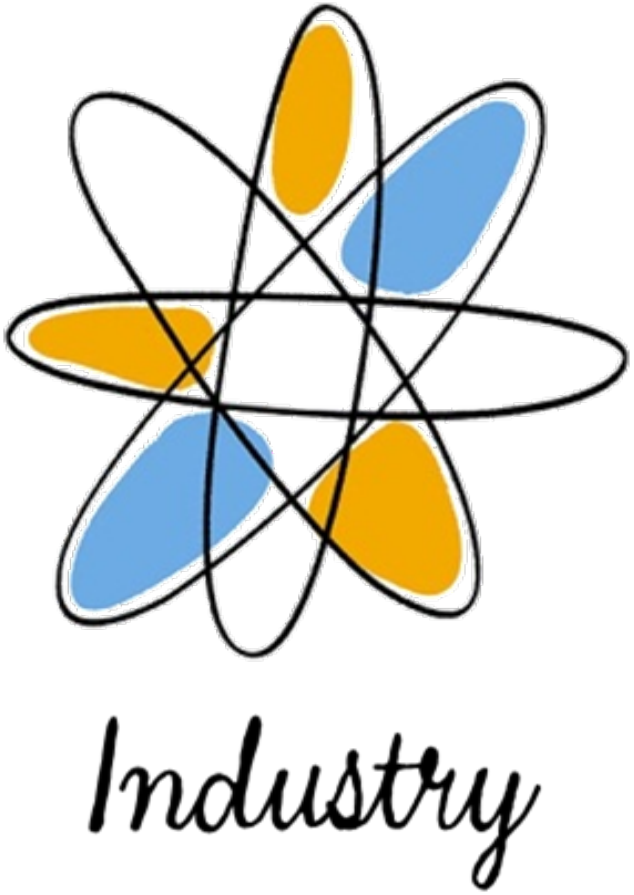
Today's Major Industry Trends



- Flash
- Cloud
- Software-defined data centers
- Data Analytics
- Mobility
- Big Data

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The Rapid Growth in Data Centers

Marshall Amaldas & Brad Nisbet, IDC 2013

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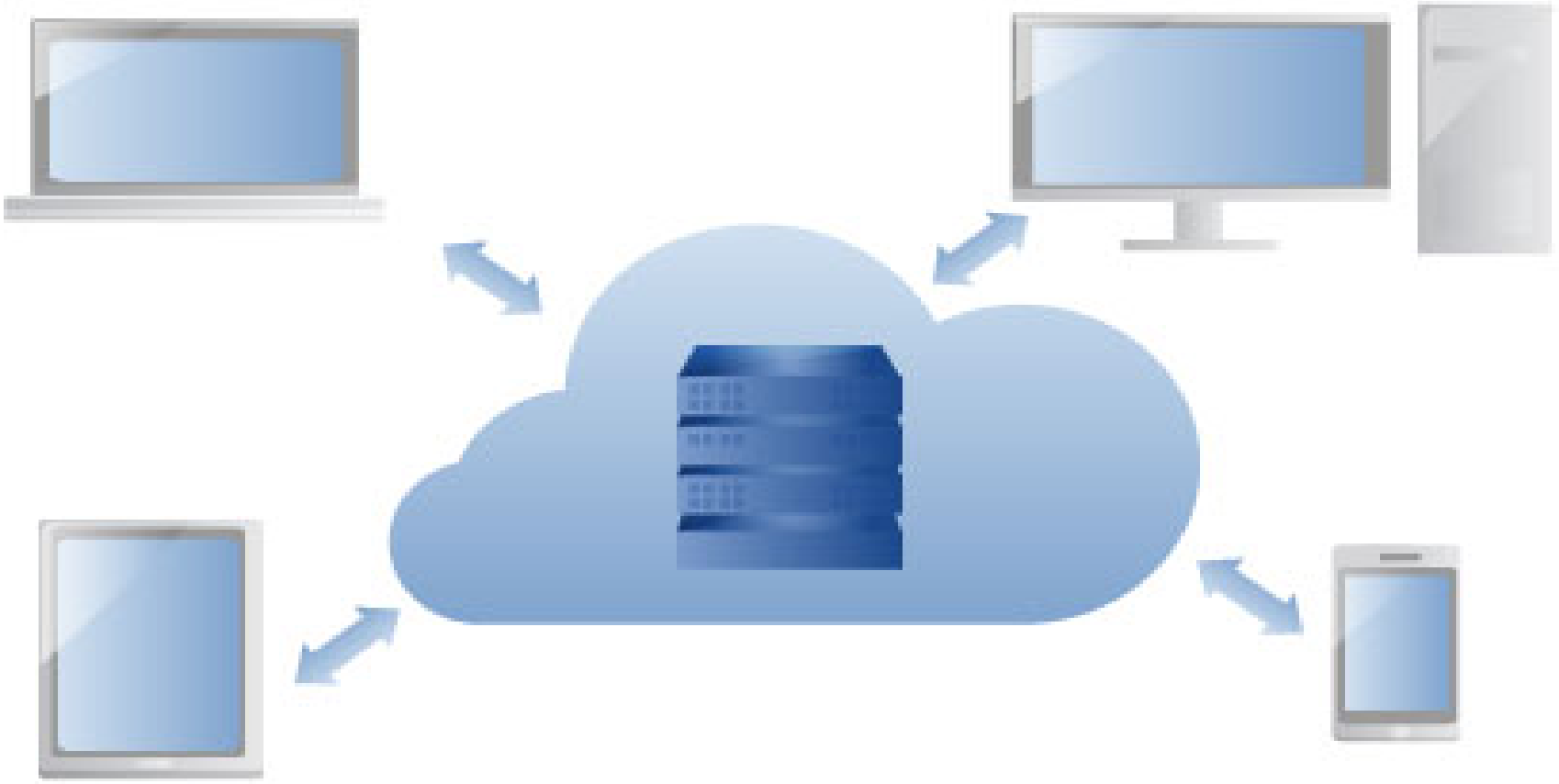
It’s all in the Cloud!



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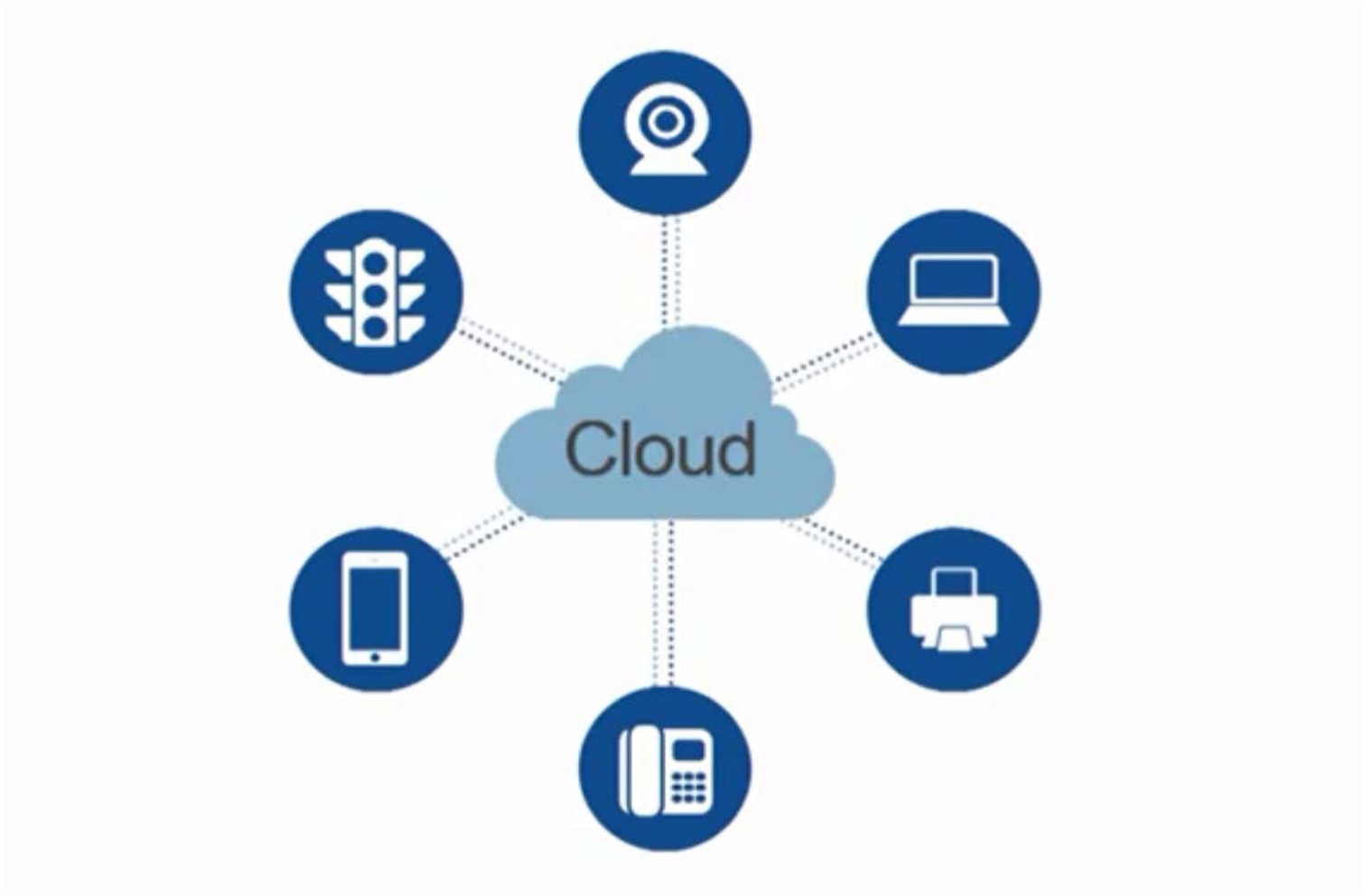
The First Wave of Cloud



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Today's Cloud and its Characteristics

Common Characteristics:

- Massive Scale
- Resilient Computing
- Homogeneity
- Geographic Distribution
- Virtualization
- Service Orientation
- Low Cost Software
- Advanced Security

Essential Characteristics:

- On Demand Self-Service
- Broad Network Access
- Rapid Elasticity
- Resource Pooling
- Measured Service

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Types of Cloud

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Private	Hybrid	Public
▪ Internal cloud ▪ Data center agility	▪ External cloud ▪ Trusted cloud	▪ External cloud

Enterprise Data Center

- Automation
- Firewall and security

Hybrids

Service Provider Data Center

Hybrids

Regional Data Center 1

Regional Data Center 2

Public Cloud

Hybrids

Private Cloud

Regional Data Center 3

Regional Data Center 4

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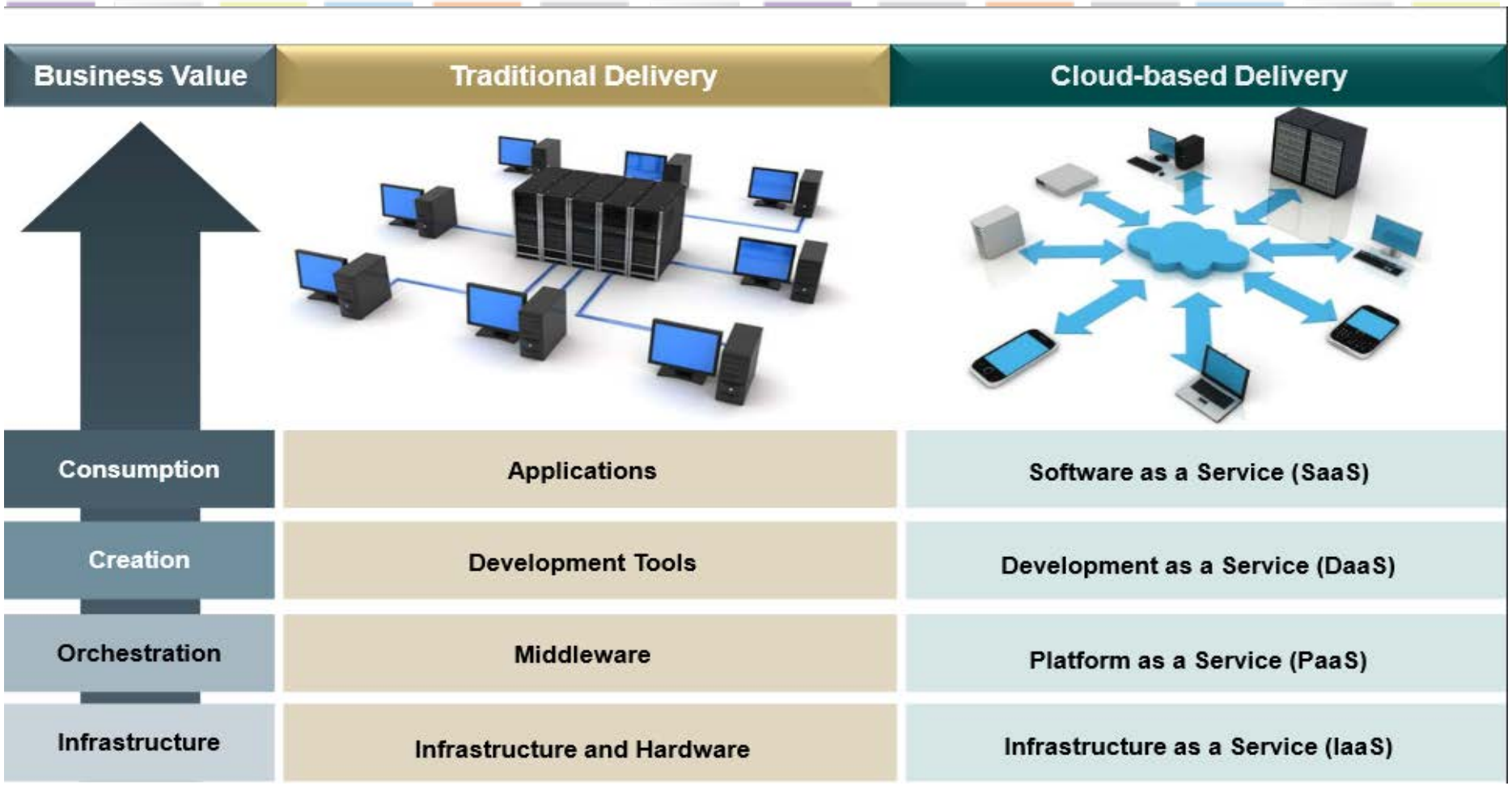
Traditional IT Delivery Translated to Cloud



Source: R Wang and Insider Associates; A Software Insider's Point of View Understanding The Many Flavors of Cloud Computing and SaaS, R "Ray" Wang, Phil Waine, Michael Cote, and James Governor; Forrester Report**; Grail Research Analysis**

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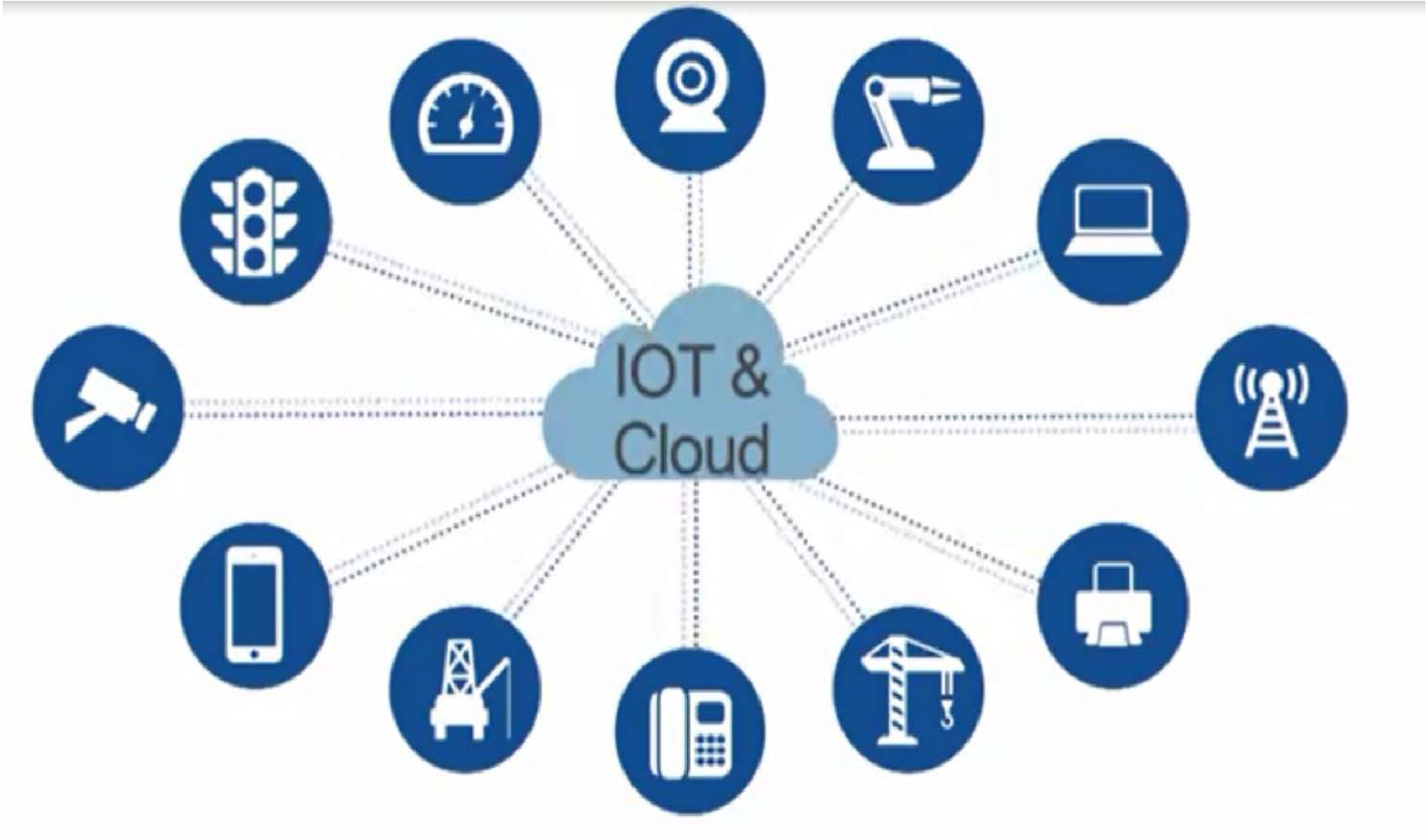
The Latest Wave of Cloud & IoT Adoption



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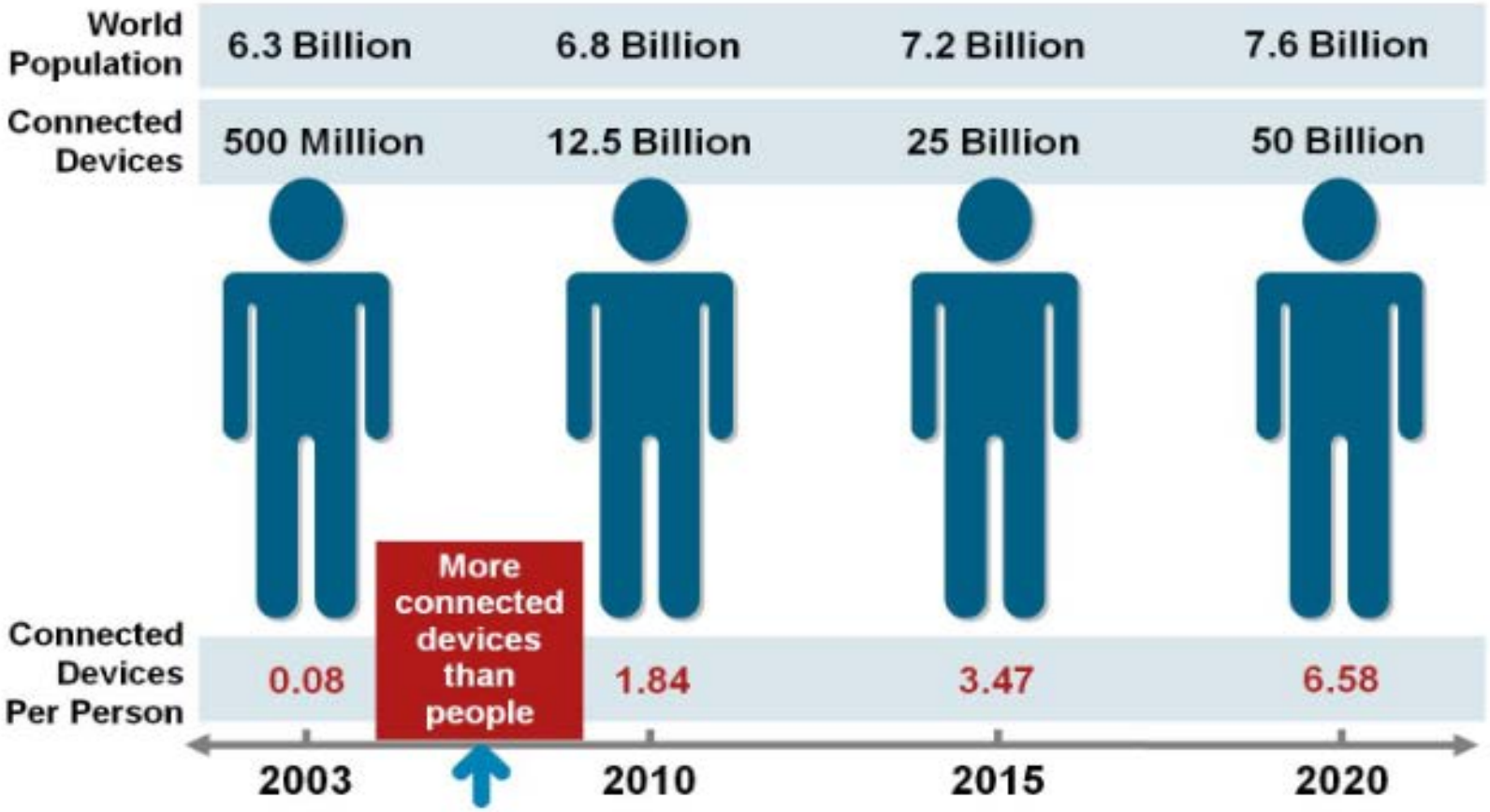
The “Birth” of IoT: Circa 2008 & 2009



Source: *The Internet of Things,* by Dave Evans, Cisco IBSG 2011.

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Now comes the IoE!

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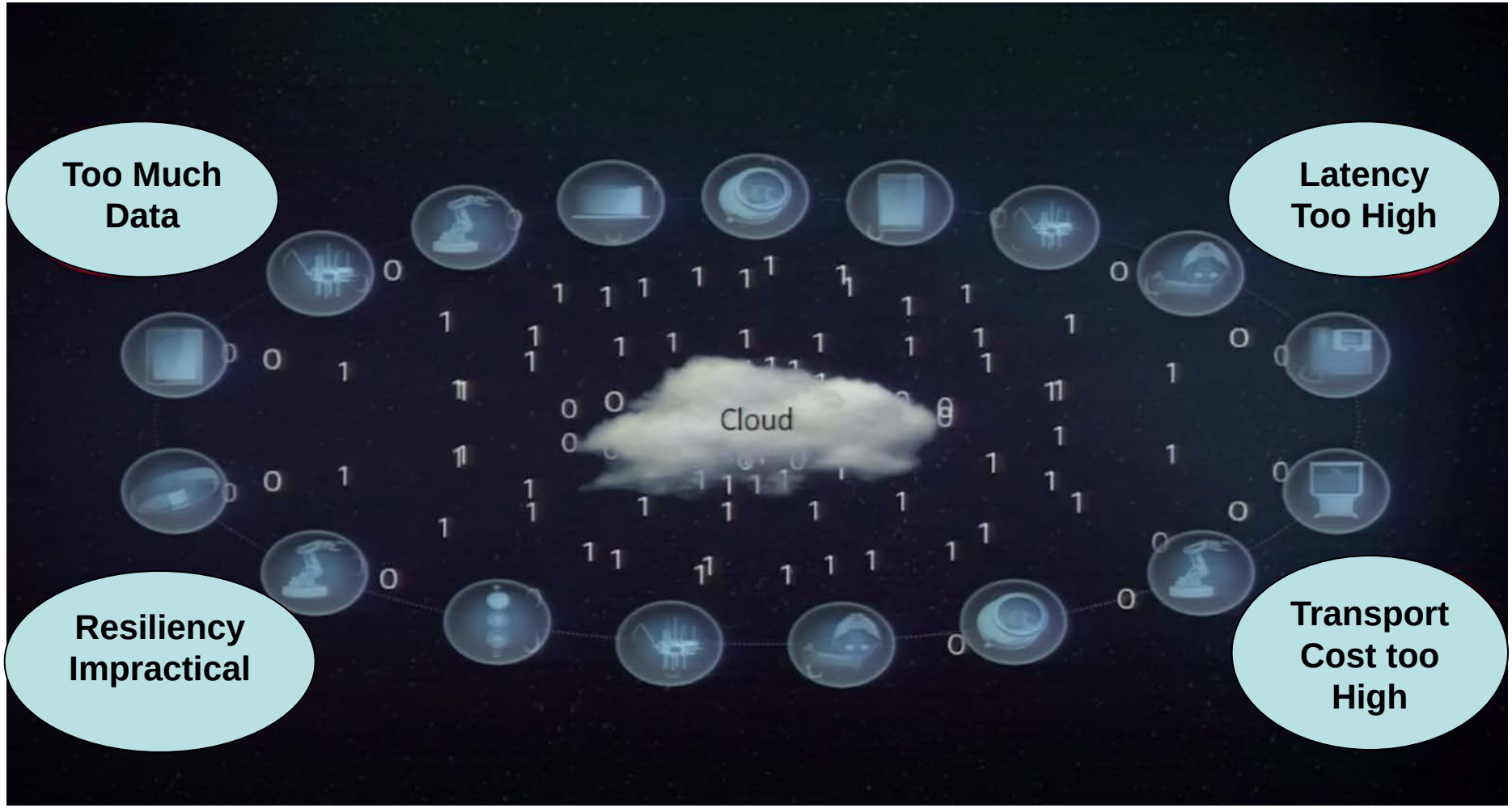
The Challenges of Cloud Computing

As more and more nodes are added to the network….



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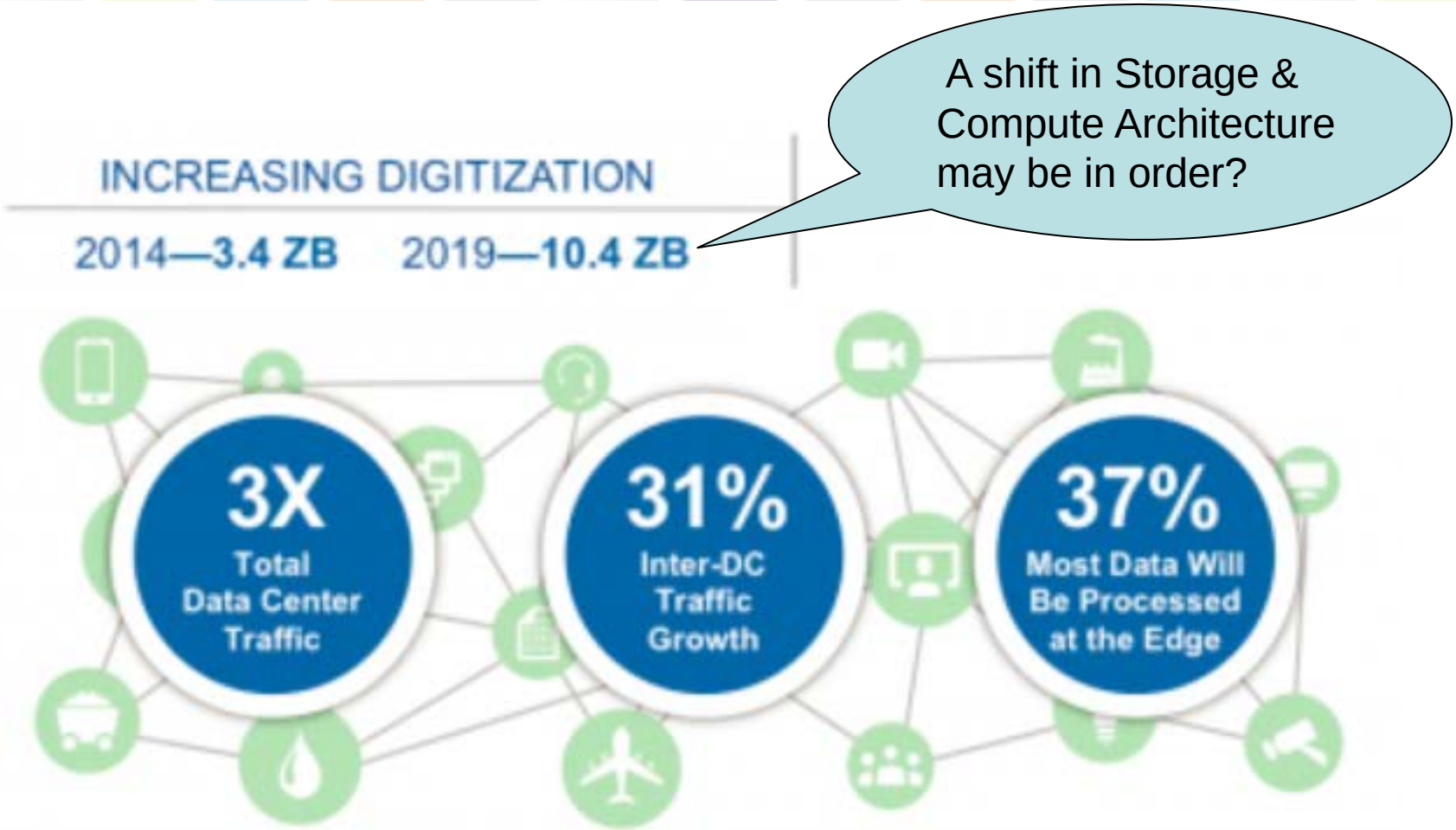
Digitizing Drives Data & Infrastructure to the Network Edge



Source: Cisco Global Cloud Index Forecast, 2014-2019, Global IoT Study.

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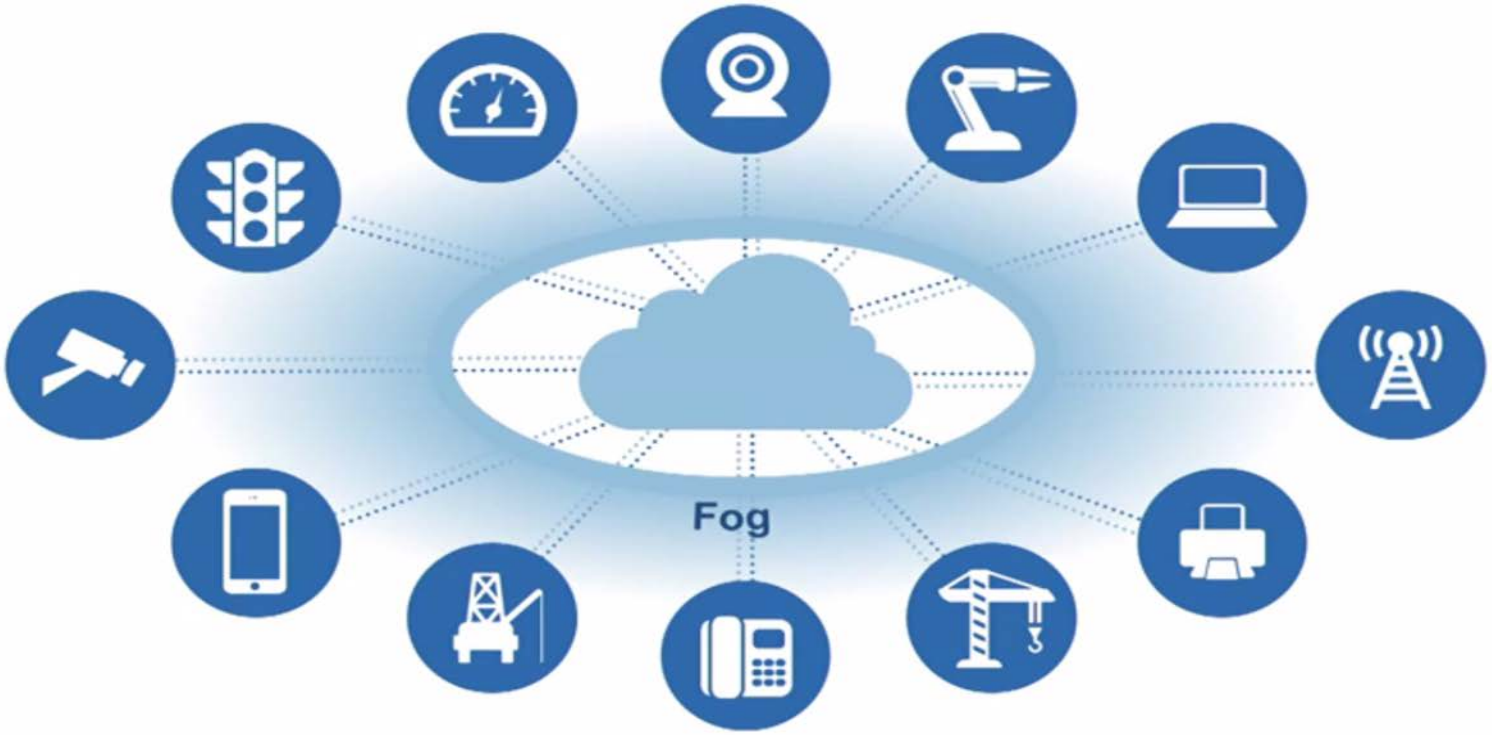
Introducing Fog Computing

Also Known As Edge Computing Throughout Industry

A paradigm that extends Cloud computing and services to the edge of the network. Similar to Cloud, Fog provides data, compute, storage, and application services to end-users.



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Characteristics of Fog Computing

- A paradigm that extends Cloud computing to the edge of the network
- Low latency & location awareness
- send the right data to the cloud for big data analytics and storage
- Wide-spread geographical distribution
- Strong presence of streaming and real time applications
- Handle an unprecedented volume, variety, and velocity of data
- Heterogeneity of connected objects
- Fog applications to communicate directly with mobile devices
- Predominant role of wireless access

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More Simplified View of Fog Architecture

Fog computing is…

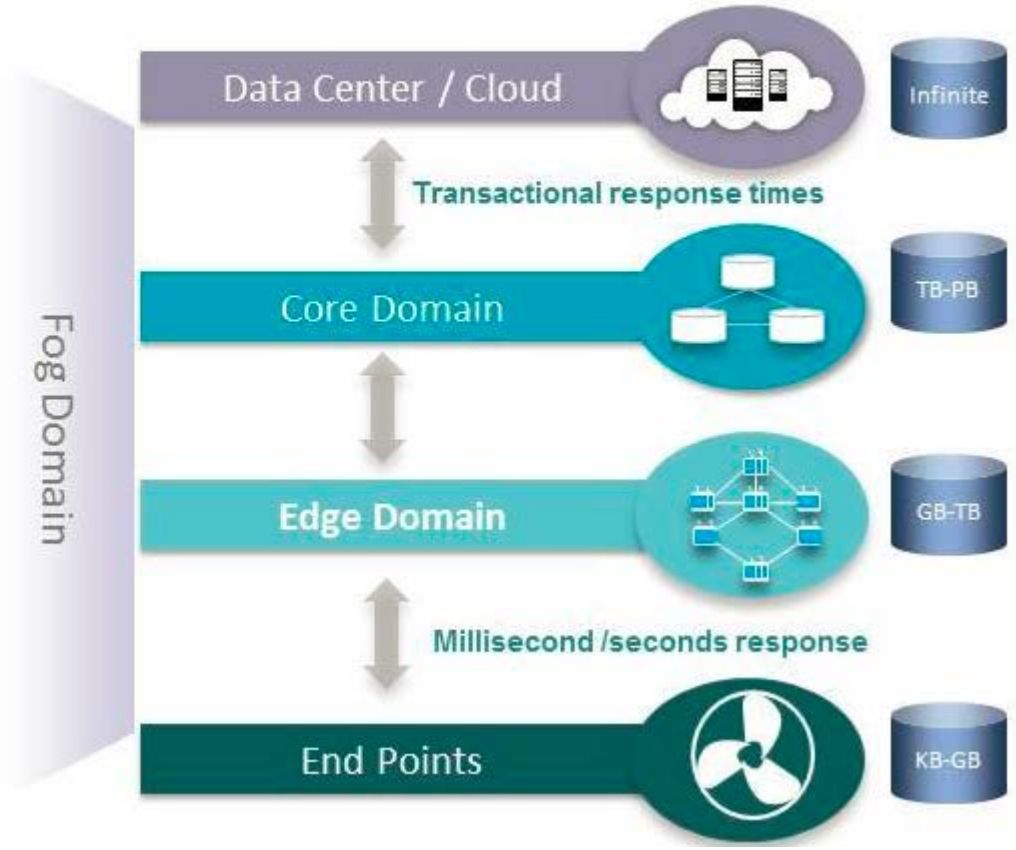
A system-level architecture to extend

Compute

Network

Storage

Capability of Cloud to the edge of the IoT network



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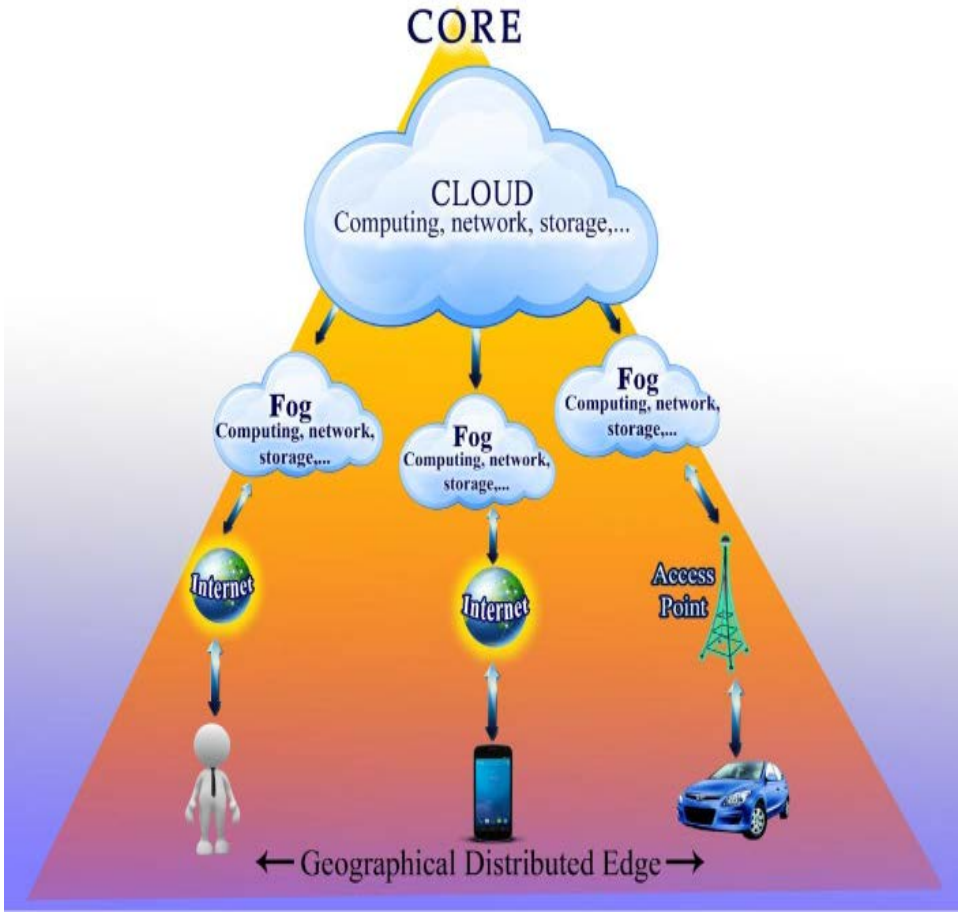
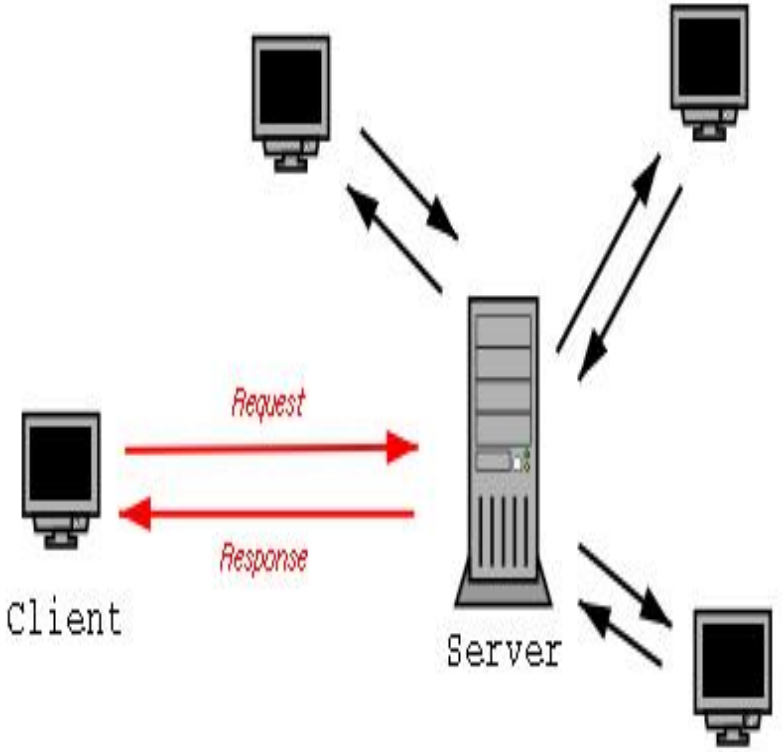
Fog Computing Vs. Client –Server Model





Source: Fog Computing Made Easy with the Help of Citrix & Billboard Manager, Journal of Computer Applications Vol. 121, No 7, Jul 2015 .

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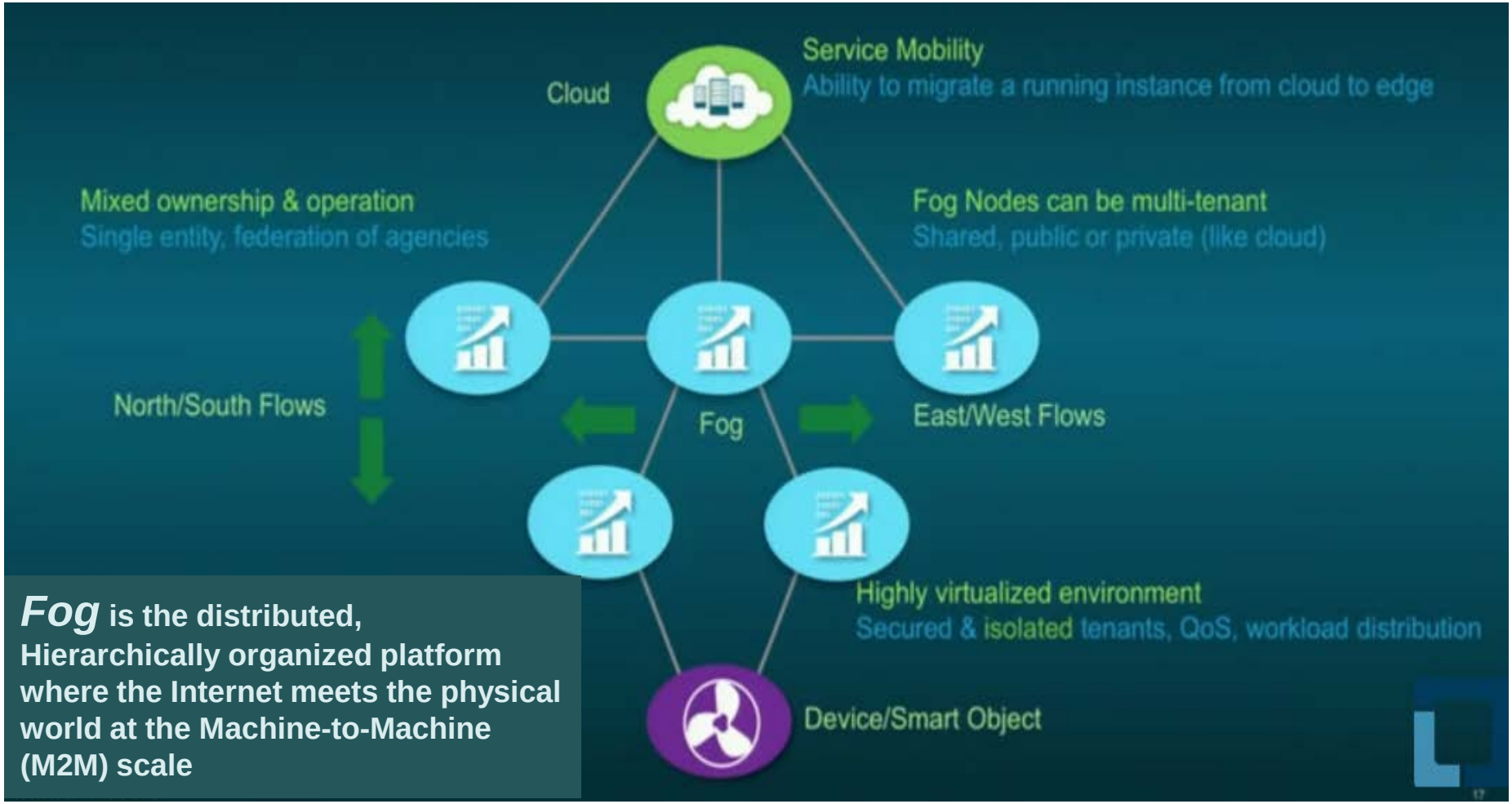
Hierarchy of Fog Computing Architecture



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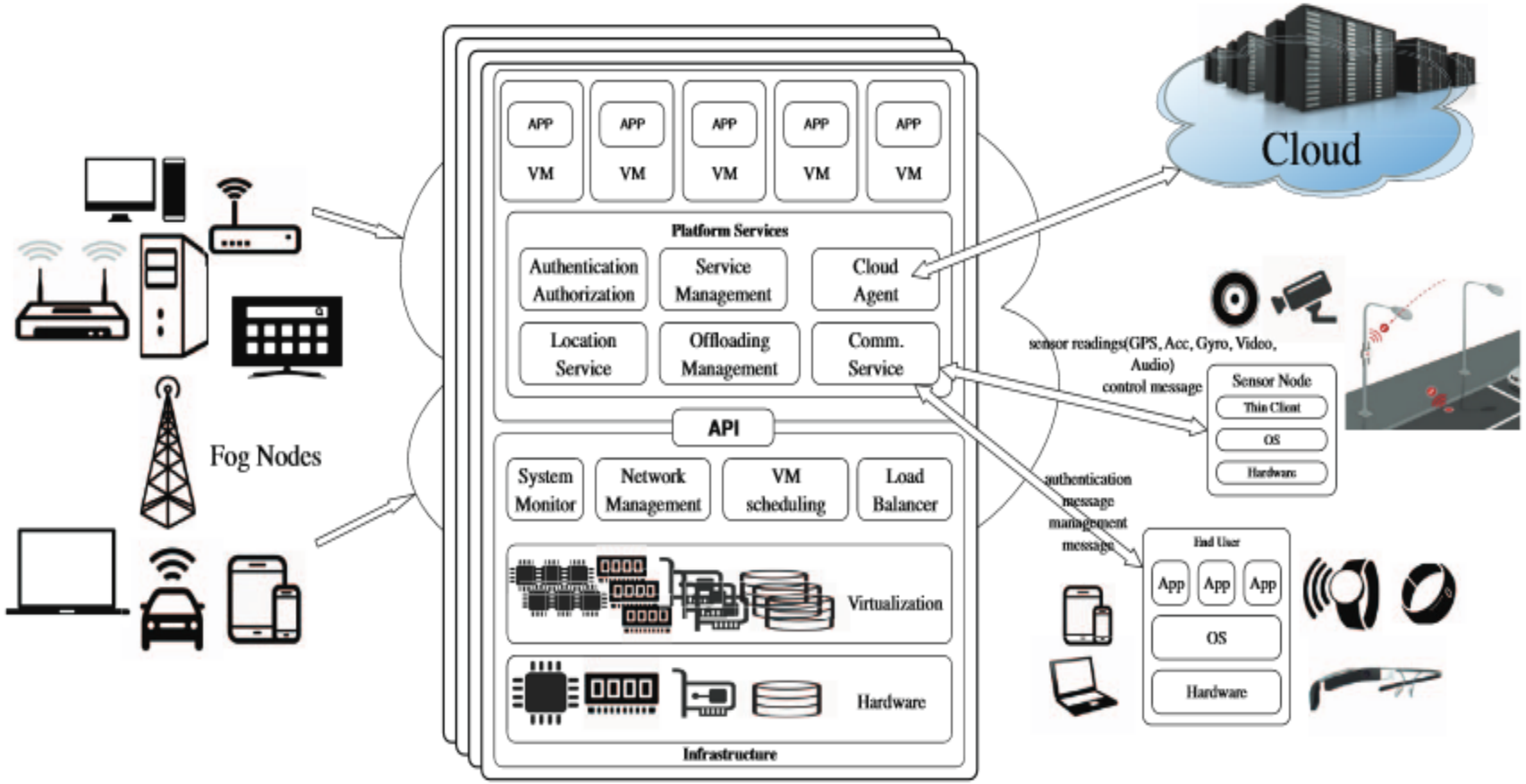
The Components for Fog Computing Platform



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Pushing Intelligence Up Toward the Cloud

Cloud Challenges	How Fog can Help
- Critical Latency Req.	+ Fewer Network hops
- Data Rich Mobility	+ Data locality & Local Caches
- Geographic Diversity	+ Intelligence localized as appropriate
- Network Bandwidth limit.	+ Local processing / less core Net. Load
- Reliability/Robustness	+ Fast Failover; local resp. in Emergency
- Analytics Challenges	+ Analytics & Storage at the Right Tier
- User Data/Geo. Privacy	+ Fog can Aggregate User Data

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Pushing Intelligence Down Toward the Endpoints

Intelligent Endpoint Challenges	How Fog Can Help
- Endpoint Physical Constraints • Energy/Power • Space • Environment (temp/, humidity & Vib.)	+ Fog nodes can access more energy + Fog Nodes can be physically larger + Better cooling systems in many Fog Nodes
- Endpoint Functional Constraints • Processor throughput • Storage capacity • Reliability • Modularity	+ Terabytes > PB storage cap. + Fog capabilities can be more redundant + Modules can be added as needed
- Endpoint Security Constraints	+ Fog has better physical/network security

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Data "Gravity" – IoT Objects generates 2EB/Day

46 million smart meters in the U.S alone 1.1 billion data points (.5TB) / day

A single consumer packaged good manufacturing machine generates 13B data samples/day

A large offshore field produces 0.75TB data/week

A jet engine produces 20TB flight data/hour

90% of the world's data created in last 2 years

Source: From Cloud to Fog Computing and IoT | LinuxCon + CloudOpen North America 2014

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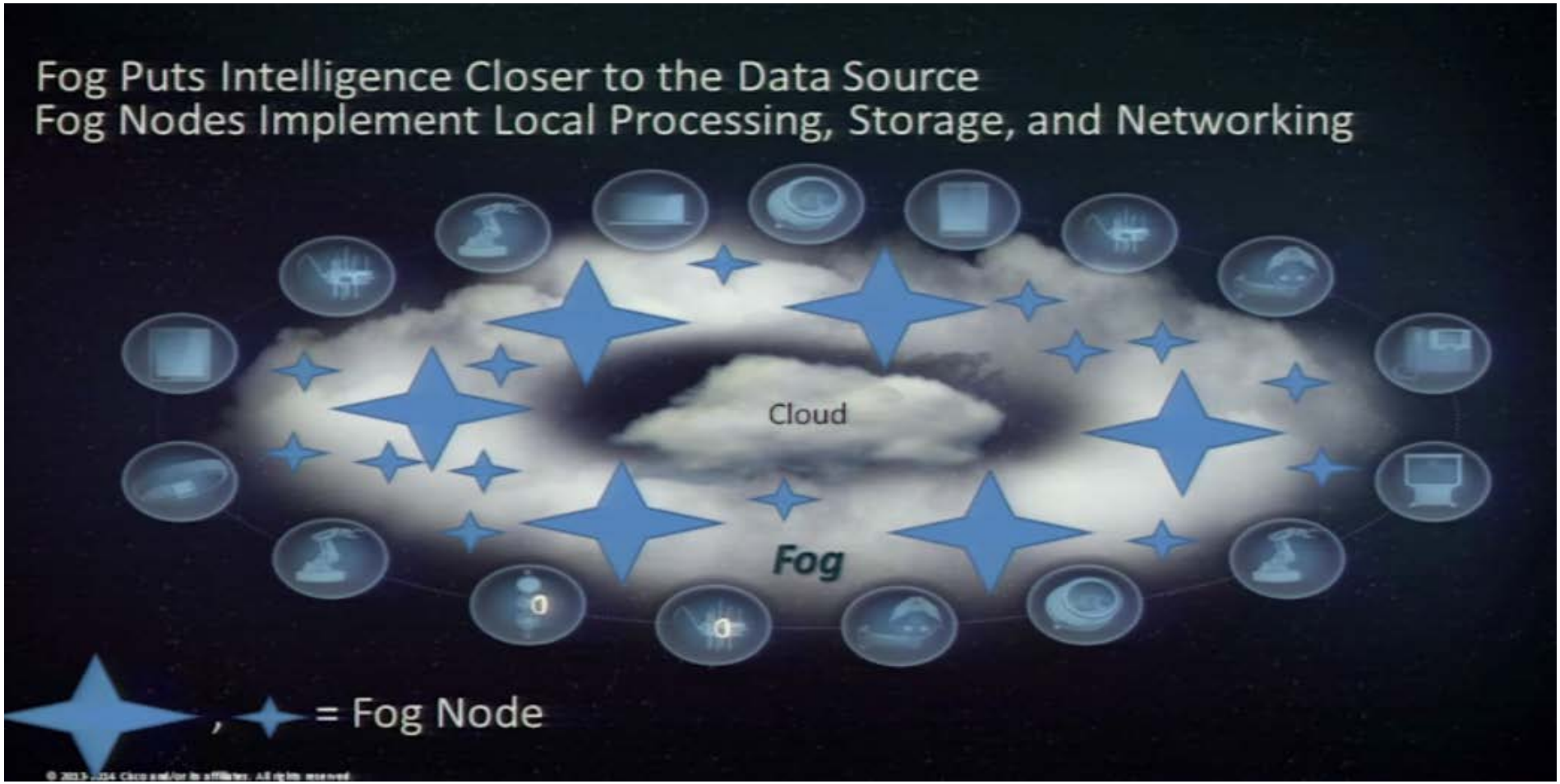
How Fog Computing can help?



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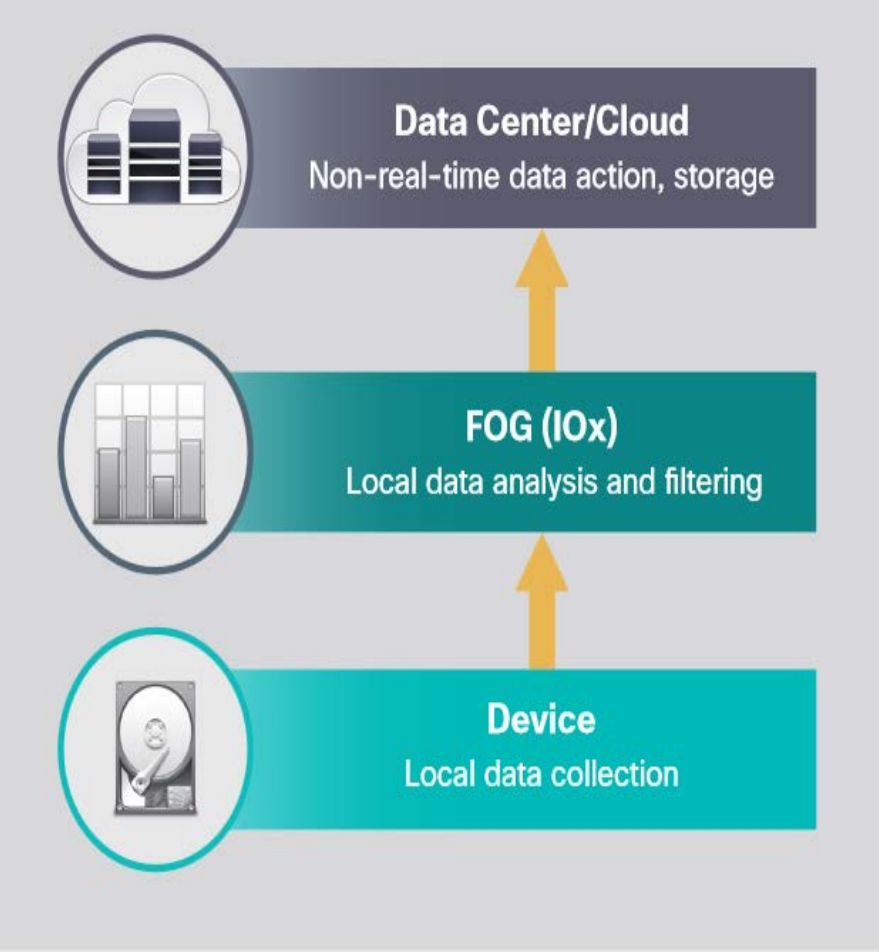
IoT with Fog Computing

At-a-Glance



What You Can Do:

- Analyze and act on data right at the network edge
- Use bandwidth and storage capacity more efficiently sending only relevant information to the cloud
- Connect any protocol or device through an open platform

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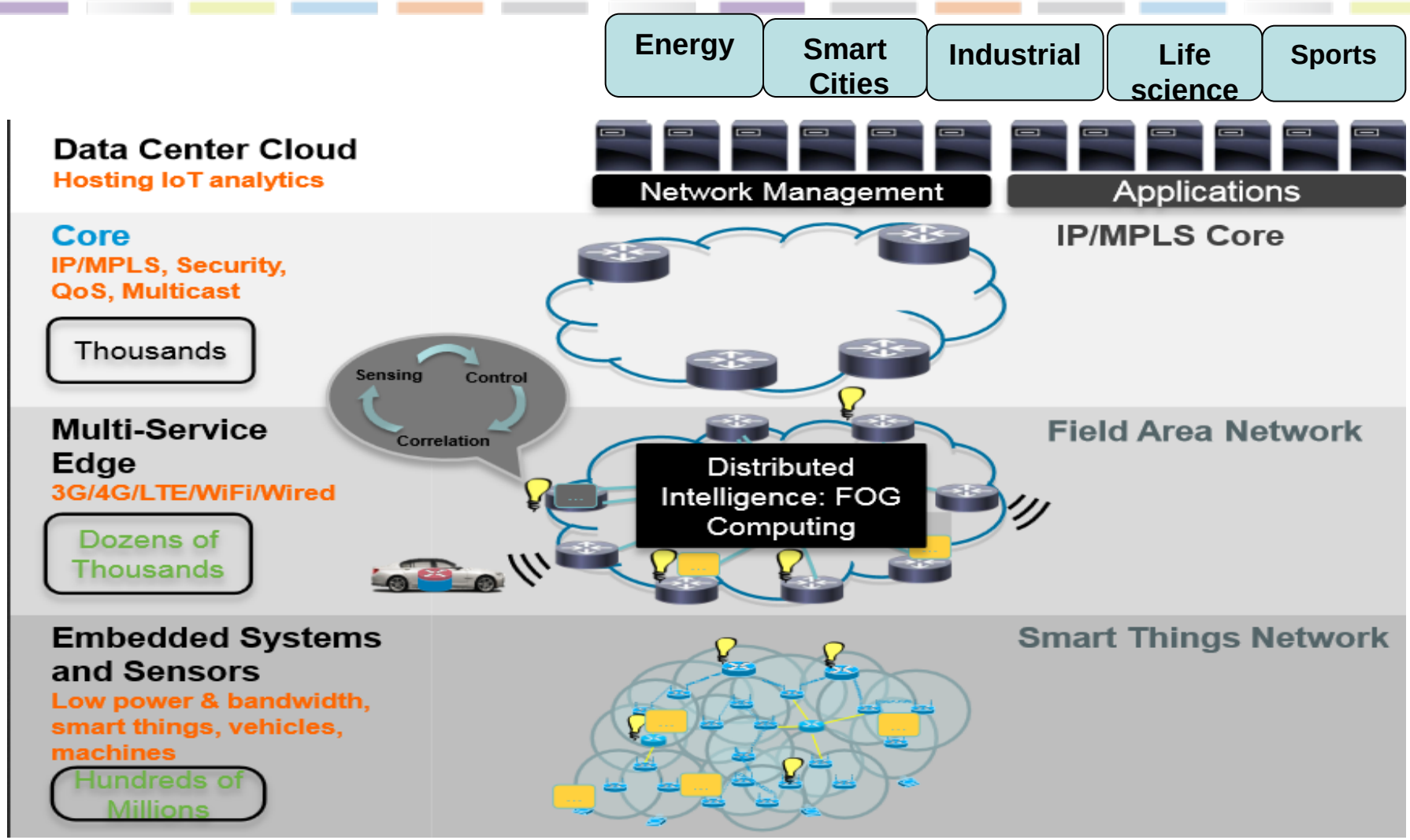
Emerging Architecture for Data Analytics Processing 1/2



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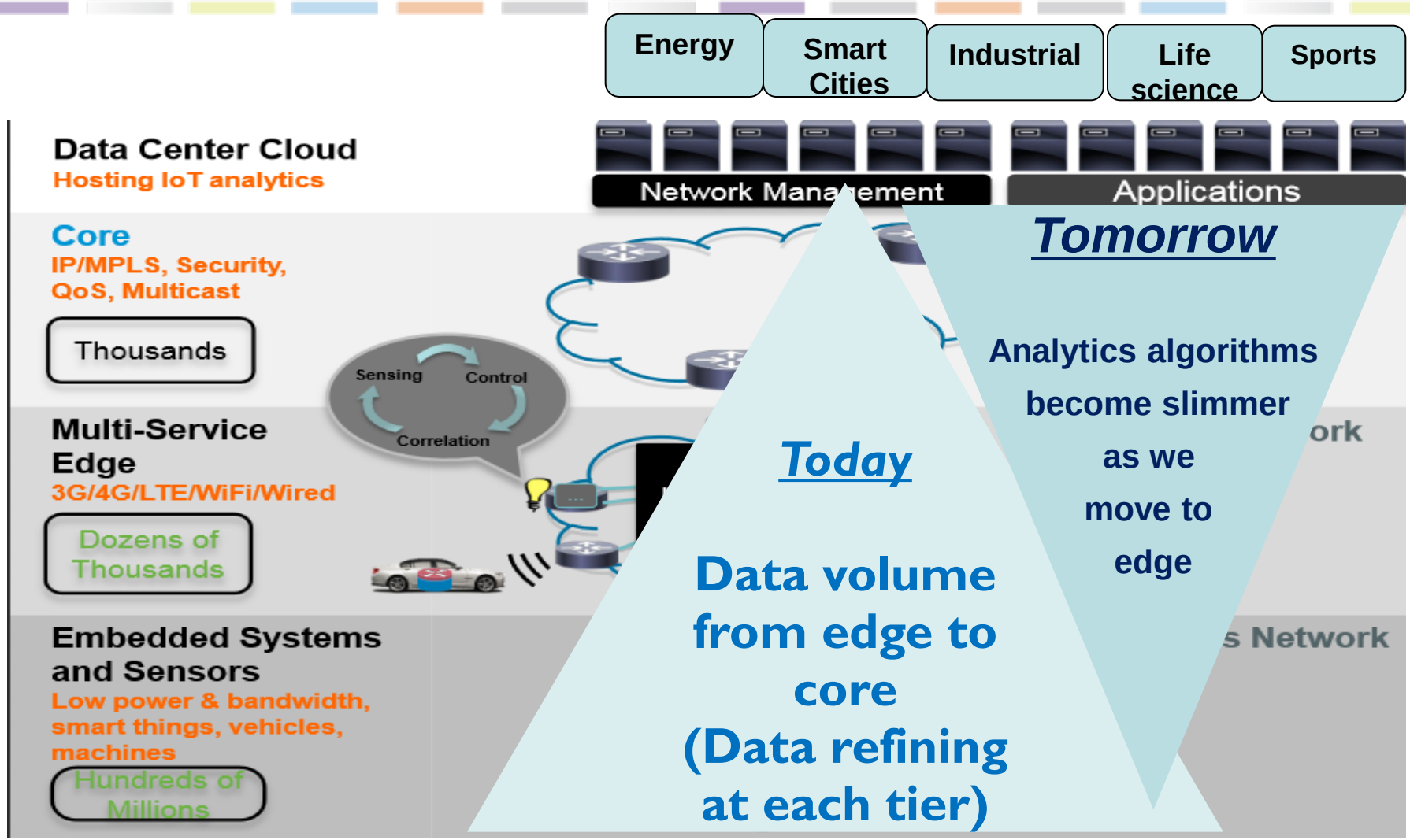
Emerging Architecture for Data Analytics Processing 2/2



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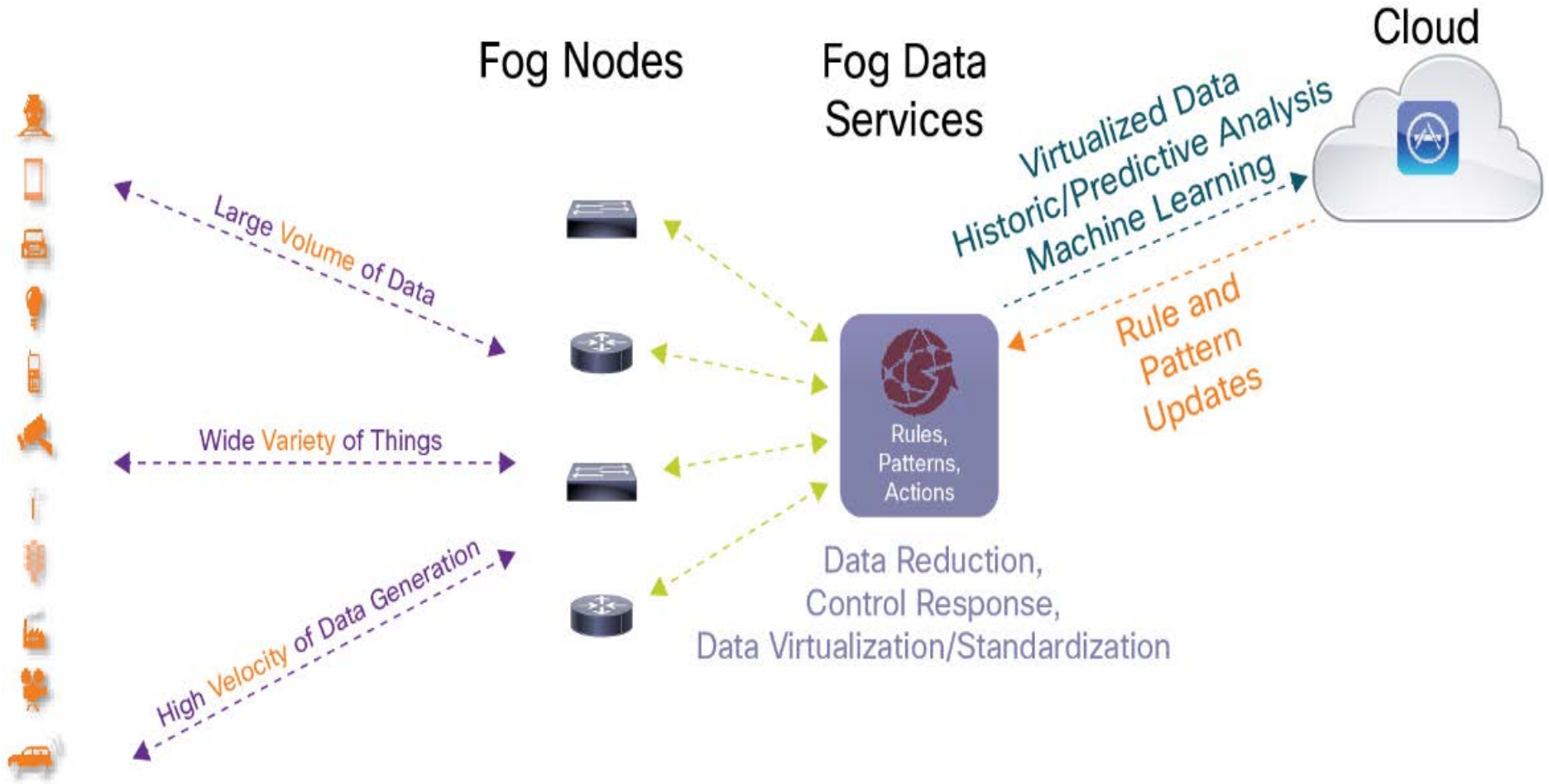
Movement of Data from Fog to Cloud

Fog Data Services Coordinate the Movement of Data from Fog to Cloud



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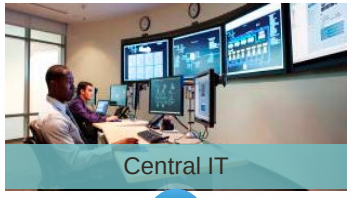
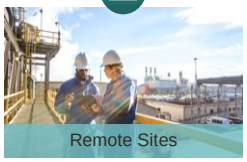
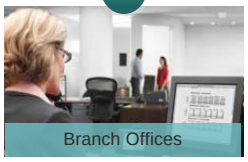
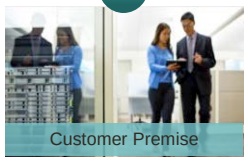
Edge Scaling Computing & Customer Needs

Computing Near the Source of Demand









Customer Needs

- Computing proximity for IoE / Fog, Remote Site, Branch
- Comprehensive remote management at global scale

Enabling Small Scale IT

Customer Needs

- "No Assembly Required" total computing solution
- Simplified systems management
- Easy scalability from 1~15 servers
- Low power / cooling footprint

IDC estimates that the amount of data analyzed on devices that are physically close to the Internet of Things is approaching 40 percent ***IDC Press Release Dec 2014***

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Compare & Contrast 1/2

Requirements	Cloud Computing	Fog Computing
Latency	High	Low
Delay Jitter	High	Very low
Location of Servers	Within Internet	At the edge close to Nodes
Distance between the client & server	Multiple hops	One hop
Security	Varies amongst providers	Can be more defined and customized
Attack on Data-in-Flight	High probability	Limited with less probability
Location awareness	No	Yes

Source: Parts taken form Fog Computing, J.HariPriyanka, April 2015, http://www.slideshare.net/haripriyanka58/fog-computing-47425209

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Compare & Contrast 2/2

Requirements	Cloud Computing	Fog Computing
Geo. Distribution	Centralized	Distributed
No. of Server Noes	Few	Very large
Support for Mobility	Limited	Supported
Real Time Interactions	Supported but may be difficult to achieve & Costly	Supported
Type of last mile connectivity	Leased line	wireless

Source: Parts taken form Fog Computing, J.HariPriyanka, April 2015, http://www.slideshare.net/haripriyanka58/fog-computing-47425209

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A Major Milestone in Fog Computing

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OpenFog™

Founders

ARM® CISCO DELL

intel Microsoft PRINCETON UNIVERSITY

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What's Next for Fog Computing?

- Identify use cases where Fog provides advantages
- Refine our views on Fog architecture
- Define an application architecture that facilitates interoperability & application migration
- Experiment with Fog APIs
- Understand how fog can help out businesses
- Doing store & compute at the edge does not undermine the importance of the center. In fact, the Data Center needs to be a stronger nucleus for expanding computing

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The SNIA Education Committee thanks the following Individuals for their contributions to this Tutorial.

Authorship History

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- **Chuck Byers, Cisco Systems**
- **Rethinking Archiving: Exploring the path to improved IT efficiency, Marshall Amaldas & Brad Nisbet, IDC, SNIA Education**
- **Research at Cisco Fog Computing, Ecosystem, Architecture and Applications**
- **Cisco Global Cloud Index Forecast, 2014-2019, Global IoT Study**
- **NetApp ACI Training on FlexPod**
- **FOG COMPUTING, J.HariPriyanka, April 2015**
- **R Wang and Insider Associates Forrester Report and Grail Research Analysis**
- **Fog Computing Made Easy, International Journal of Computer Applications vol 121, No 7, Jul 2015**
- **IDC Reveals Worldwide Internet of Things Predictions for 2015**

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