
University of Colorado Boulder

Fundamentals of Data Communications

Cloud Computing and Internet of Things (IOT)

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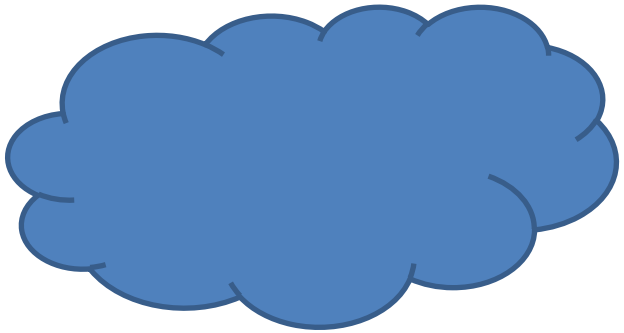
Review

- **OSI**
- **Switching**
- **Network**
- **ARP**
- **Routing**
- **Security**
- **IP Addressing**
- **Wireless**

Cloud Computing

- **Using network of remote servers hosted on the Internet**
  - Store (storage), manage ("as a service"), process (compute)
  - Do not use local server or PC

- **Cloud = "Internet"**



Cloud Computing

- **On-demand delivery of IT resources and applications via the Internet**
  - Pay as you go

- **Traditional data center**
  - Economies of scale
  - New application implementation/innovation
  - Add/remove elastic needs
  - Scalability

Data Center (DC)

- **Densely packed racks of high-powered computers and storage**
  - Tremendous amounts of compute power in a single room

Cloud Benefits

- **Save Money**
  - No large upfront investments in hardware
  - Managing hardware
  - Provision the right type/size of compute resources
  - Pay for what you use

Cloud Benefits

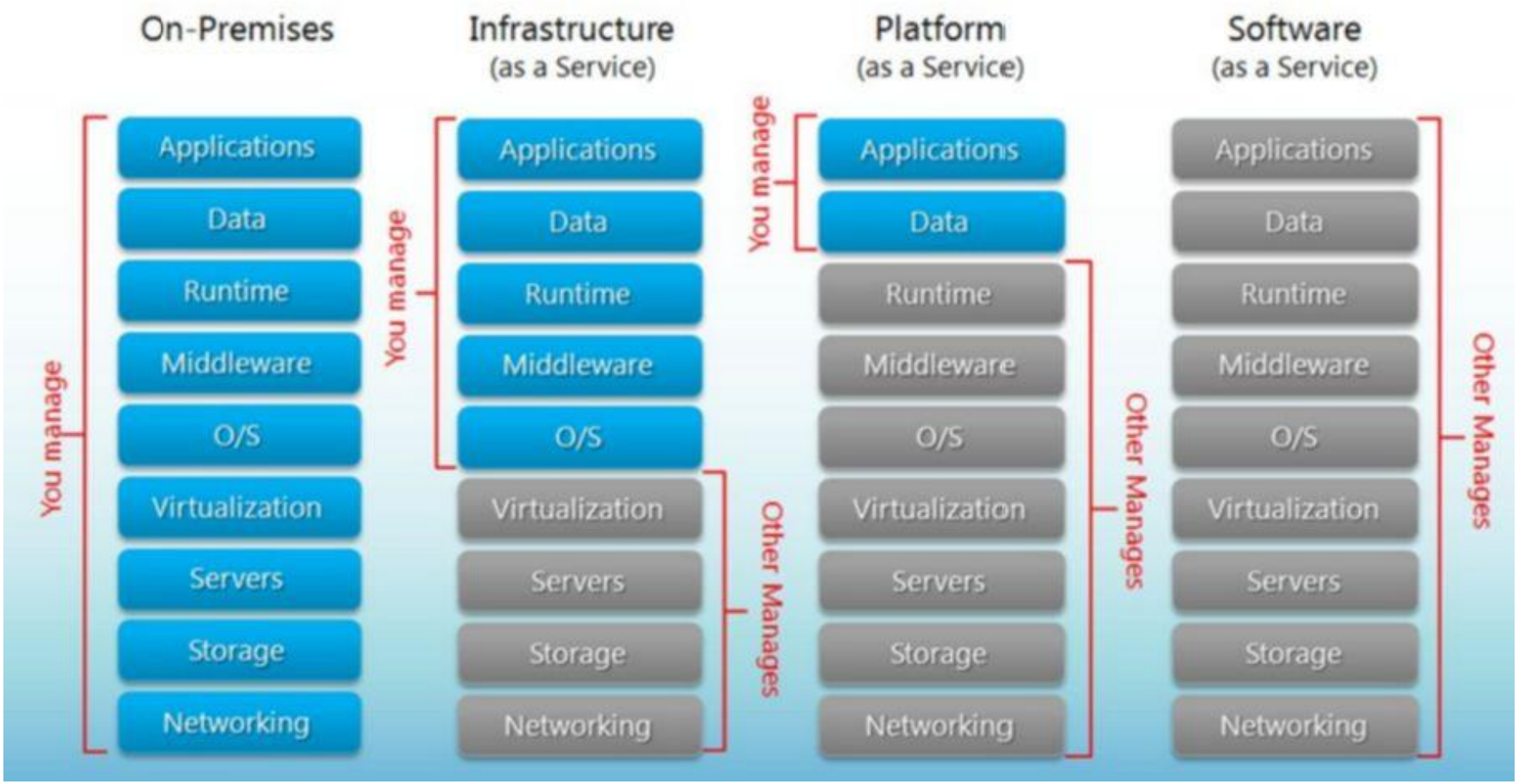
- **CAPEX vs. Variable Expenses**
- **Economies of scale**
- **No budget for capacity**
- **Speed and agility**
- **Innovation not infrastructure**
- **Global**

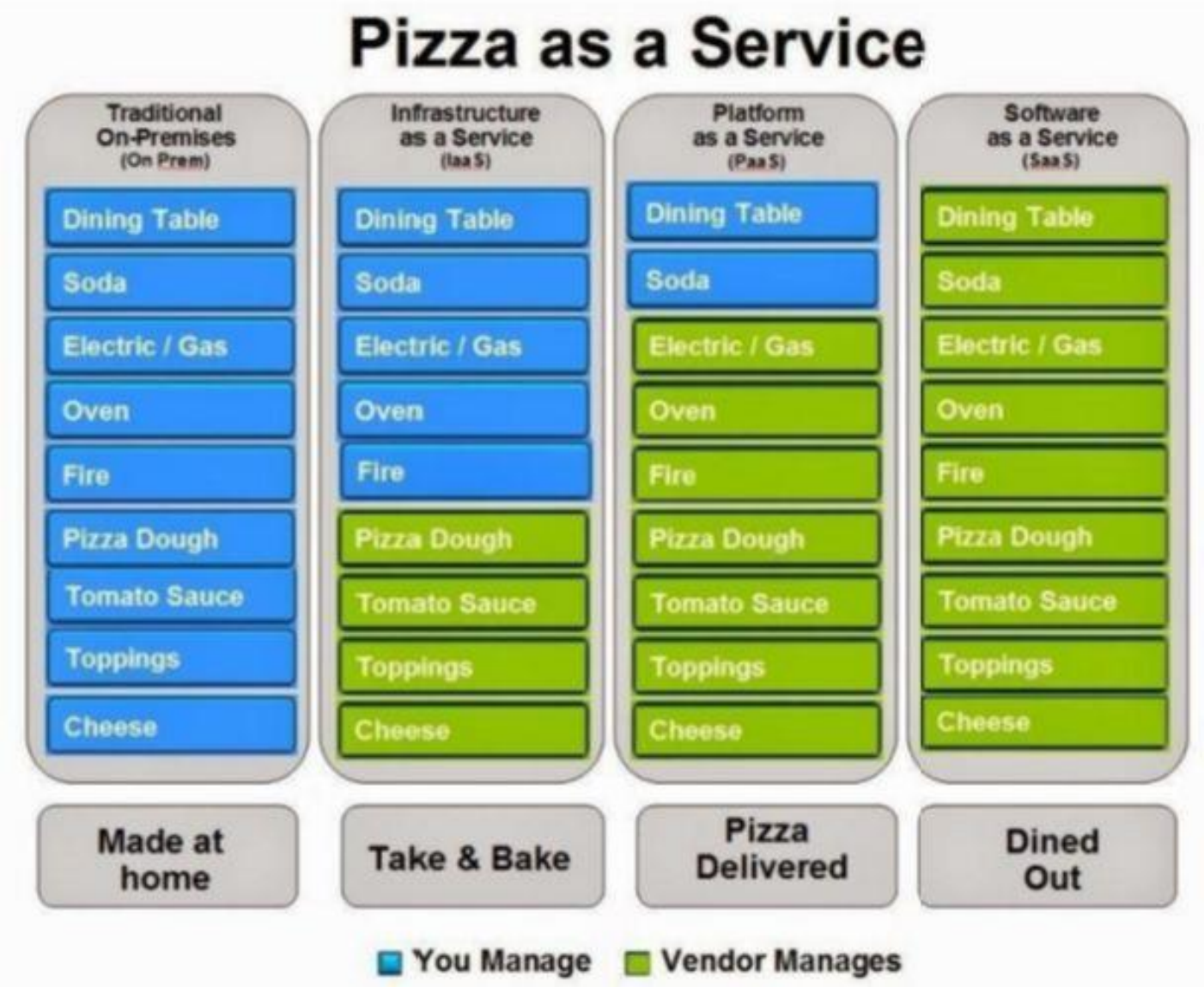
Cloud Benefits – NIST Essentials

- **On-demand self-service**
  - Agility and cost
- **Broad network access**
  - Device and location independence
- **Resource pooling**
  - Performance and productivity
- **Rapid elasticity**
  - Reliability and scalability

DC Cloud Business Models

- **Virtualization**
- **Infrastructure – IaaS**
  - No need for hardware
  - Amazon (AWS), Microsoft Azure, Google Compute Engine, Rackspace – “Rent out” Backbone network
    - ***Netflix & Pinterest use Amazon***
- **Platform – PaaS**
  - You manage your applications and software
- **Software – SaaS**
  - Largest cloud market
  - Deliver applications that are managed by third-party vendor
  - Typically use web browser
    - ***Salesforce.com – customer relationship management***
    - ***Concur – expense reporting***
- **Networking - NaaS**
- **Shifts CAPEX to OPEX**


On-Premises
Infrastructure
(as a Service)
Platform
(as a Service)
Software
(as a Service)
Applications
Data
Runtime
Middleware
O/S
Virtualization
Servers
Storage
Networking
You manage
You manage
You manage
Other Manages
Other Manages
Other Manages


Pizza as a Service
Traditional On-Premises (On Prem)
Infrastructure as a Service (IaaS)
Platform as a Service (PaaS)
Software as a Service (SaaS)
Dining Table
Soda
Electric / Gas
Oven
Fire
Pizza Dough
Tomato Sauce
Toppings
Cheese
Made at home
Take & Bake
Pizza Delivered
Dined Out
You Manage
Vendor Manages

DC Categories

- **Private single-tenant**
  - Individual organizations that maintain their own data centers
- **Private multitenant**
  - Organizations that provide specialized DC services for other client organizations
    - ***Contracts to specific clients***
- **Public multitenant**
  - Generalized DC services to anyone (individuals or public)

DC Categories - Cloud

- **Public cloud**
  - Service provider makes services available to public over the Internet
    - ***Microsoft Azure***
    - ***Amazon***

- **Private cloud**
  - Server and network resources assigned to specific client; though, hardware owned by provider

- **Hybrid cloud**
  - Resources dedicated to a single tenant, but parts are shared with other tenants
    - ***Shared resources up/down on demand***
    - ***Major driver in SDN in the DC!***

Major Players – Consumer vs. Business

1. **Amazon Web Services (AWS)**
2. **Microsoft Azure**
3. **IBM**
4. **Google Cloud Platform**
5. **Oracle**
6. **Salesforce.com**
   – SaaS

Google Cloud Platform (GCP)

- **Services**
  - Gmail
  - Calendar
  - Maps
- **Google Drive**
  - Storage
  - Cloud Apps
    - ***Docs, sheets, slides, etc.***

Google Cloud Platform

Cloud Hardware Access

- **Legacy Dumb Terminal**

- **Current Dumb Terminal**
  - Web browser = “operating system”
  - IOT!!

Downside of the Cloud

- **ISPs control your access**
  - Internet failure
- **Terms of service**
  - Increase in “rent”
    - ***Lock in?***

Downside of the Cloud

- **Security**
  - IP - Who owns the data you store online?
    - ***What if you create it in a cloud software (Google Docs)***
  - Private company
  - Other companies on same network/servers

- **Interdisciplinary - No governing body use of cloud for storage and services!**

Internet of Things (IOT)

IOT or IOE (Everything)

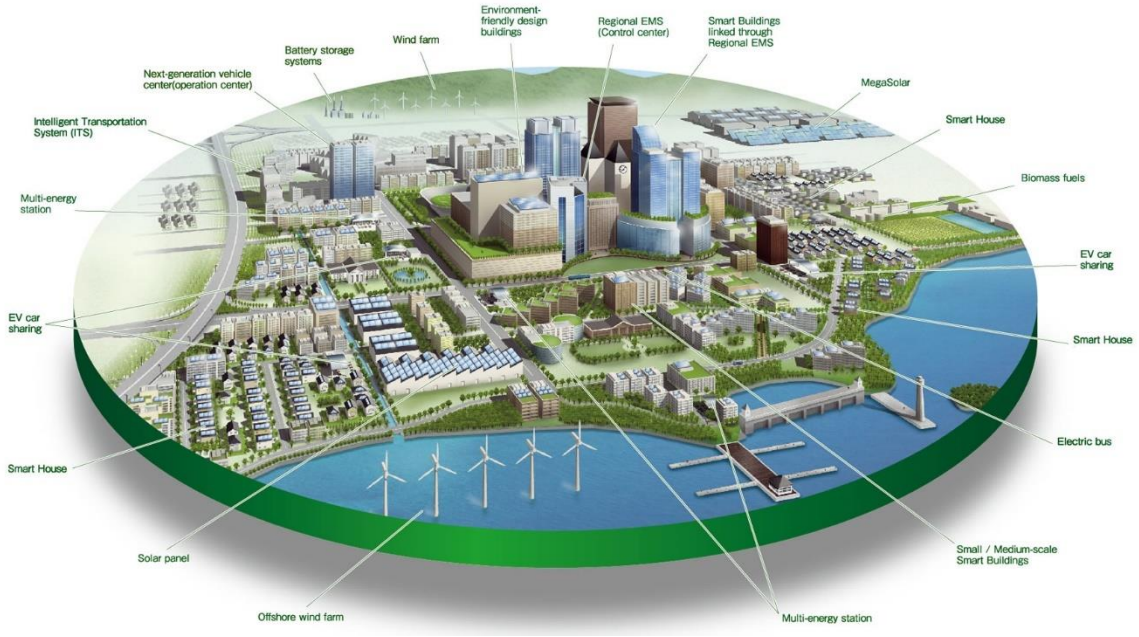
- **Everyday objects have network connectivity allowing them to send/receive data**
- **“Everything is smart”**
- **Terms – “connected devices” & “smart devices”**
- **50 billion objects 2020 (Cisco)**

Facilitators

- **Ubiquitous wireless connectivity**
  - Bluetooth, ZigBee, Z-Wave, LTE/5G
- **IPv6**
- **Cloud**
- **Inexpensive hardware**
  - Moore's Law
    - ***Raspberry Pi***
    - ***Arduino Yun***

Smart Cities & Grids

- **Transport & Traffic management**
- **Energy**
- **Health care**
- **Water**
- **Waste**
- **Urban agriculture**



Sensor Networks

- **Object that detects events or changes and send info**
  - Light, temperature, sound, pressure, etc.

- **Turns information into action**
  - Concrete (bridges)
    - ***Structural engineering***
  - Vehicles
    - ***Hazard ahead, slow down***
  - Smart Grids
    - ***Stoplights not on timers, but based on traffic flow***

Home Technology Integration (HTI)

- **Smart Home / Home Automation**
  - Lighting
    - ***Scenes***
  - Sprinklers, Blinds, Locks, GPS, Refrigerator, Laundry, etc.
    - ***FIBARO Home Automation Demo***

- **Retrofit**
  - Wireless
  - Historic

HTI

- **Security**
  - Camera
  - Smart Phone
  - Multi-tenant Dwelling

Home Automation Controllers

- **Google Home**

- **Apple HomeKit**

- **Amazon Alexa**

amazon alexa

- **Wink**

Security & Privacy

- **Mirai Botnet**
- **Targeting**
  - Wearables
    - ***Behavior statistics***
      - Exercise, travel, shopping
  - Marketing / advertising
    - ***Thermostat = blankets***
- **Home automation**
  - Door locks
  - Washing machine – intruder
  - Cut Internet access
- **Sports**
  - Blood type
  - Nutrition
  - Heart Rate & power

Security & Privacy

- **Vehicles**
  - Brakes
- **Smart grid / city**
  - Power
  - Speed limit
  - Stop lights
    - ***"Italian Job"***
- **Health care**
  - Pacemaker
- **"Big Brother"**
  - Off the grid?

Issues

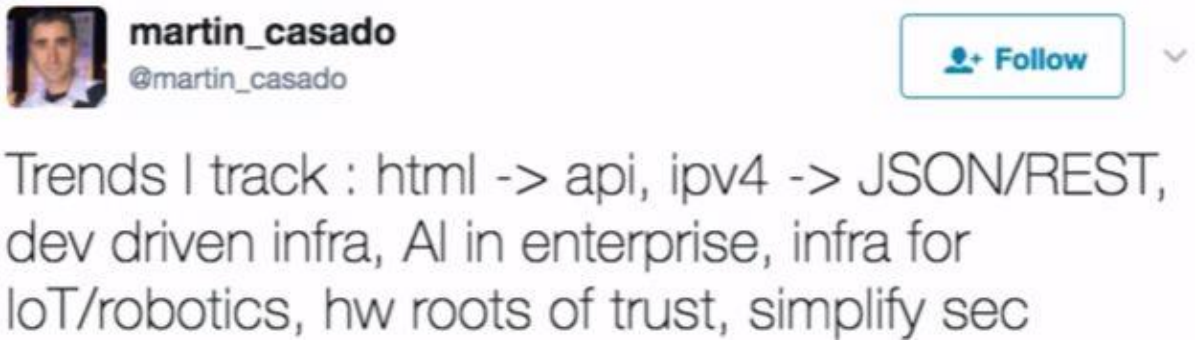
- **Underestimation of negative effects**
  - Radiation from billions of wireless devices
- **Government regulation and policy enforcement**
  - How?
  - Drones?
- **Legacy devices**
  - Technology increases, what about the “original” IOT devices?
- **Security and Privacy**
  - The concept of privacy is going to be re-written

Software is Eating the World! – M. Andreessen (2011)

- **Software has revolutionized/disrupted entire industries**
  - Zoom
    - ***Interactive meetings***
      - Metaverse
  - Netflix
    - ***Movie rentals***
  - Uber
    - ***How many taxies does Uber own?***
  - AirBnB
    - ***How many hotels does AirBnB own?***
  - Amazon
    - ***Where is there store front?***
    - ***What about their bookstore?***
  - Social Media
    - ***fb, twitter, linkedin, pinterest, Instagram, snap, tiktok***

Networking

- **SDN**
- **NFV**



- **Network programmability & automation**
- **CCIE vs Python (search Internet)**

Future of Networking?

Questions?