



University of Colorado **Boulder**

Fundamentals of Data Communications

Cloud Computing and Internet of Things (IOT)

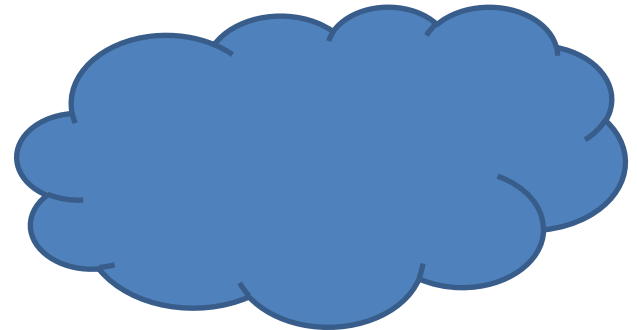
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Review

- **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**

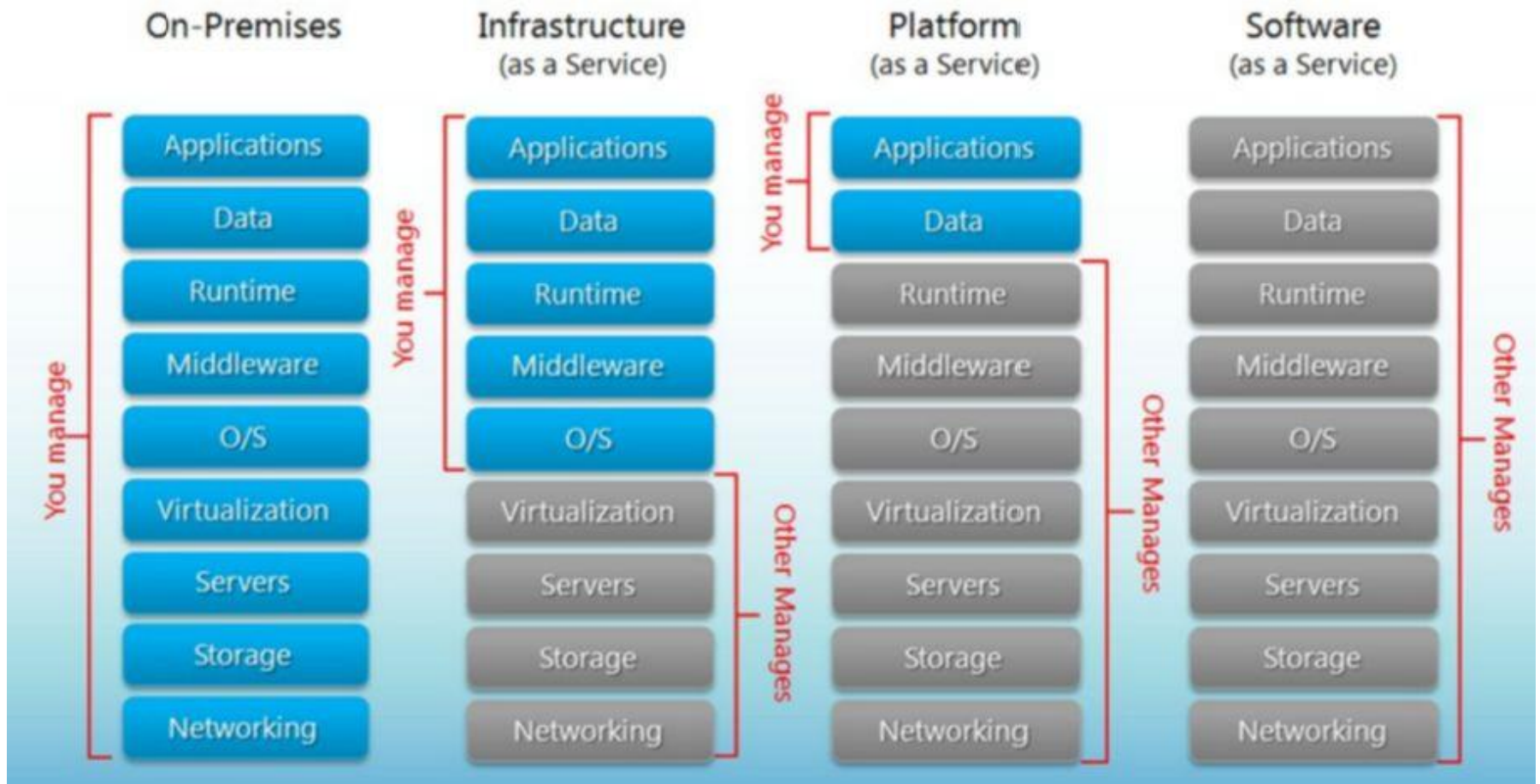
Cloud Benefits – NIST Essentials

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

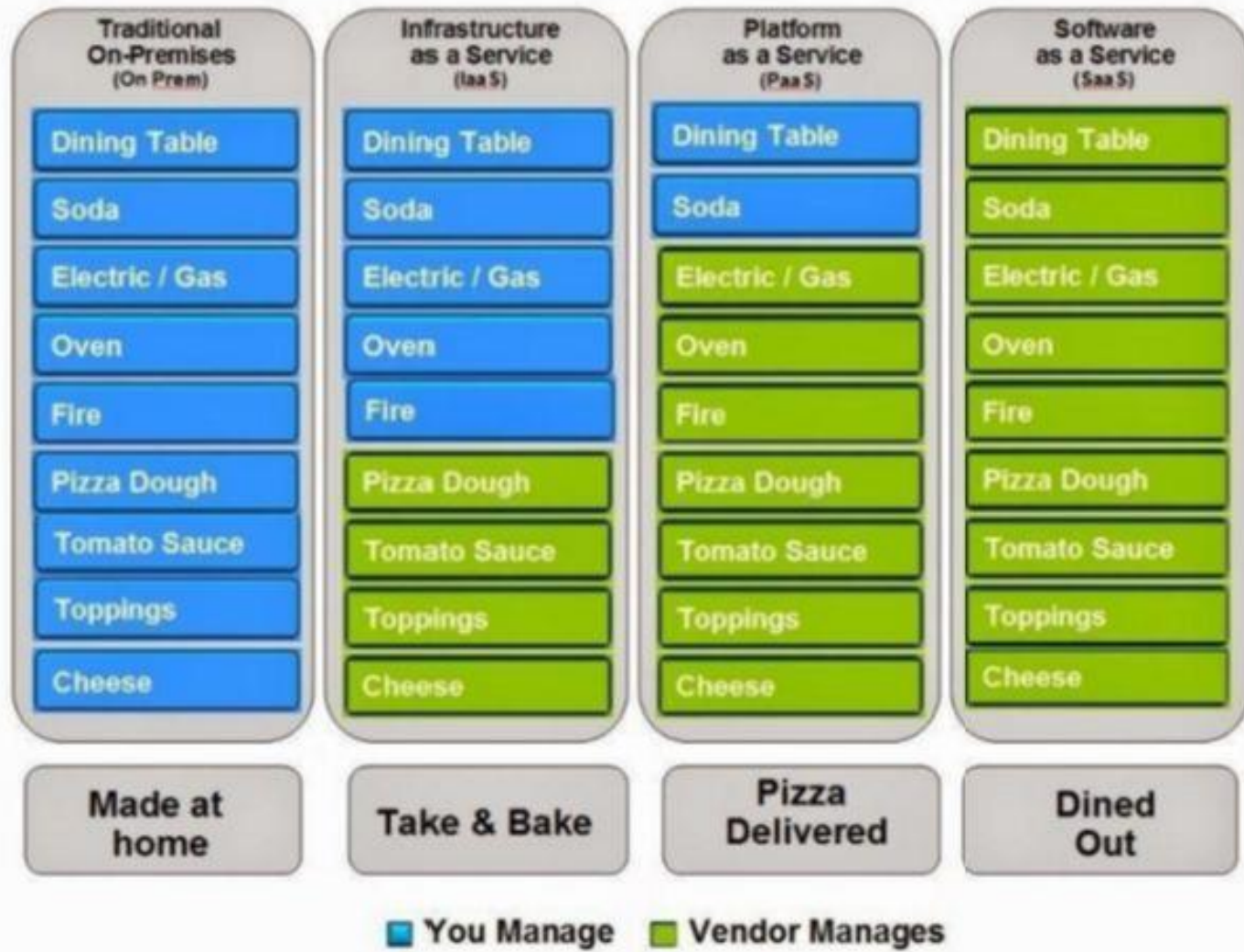
DC Cloud Business Models

- **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**





Pizza as a Service



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**

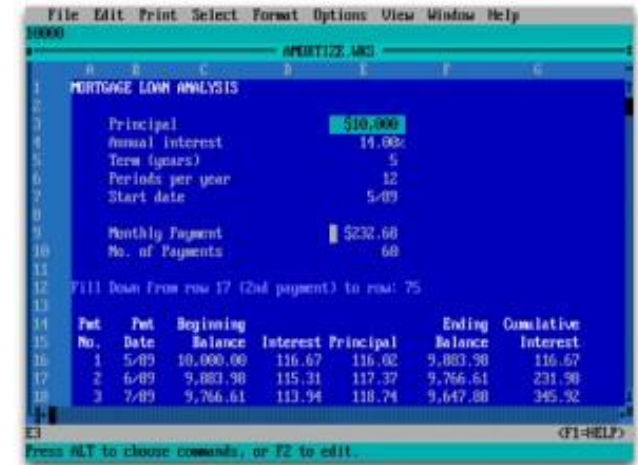
- Storage
- Cloud Apps
 - *Docs, sheets, slides, etc.*



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**
- **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
- **Health care**
 - Pacemaker
- **Smart grid / city**
 - Power
 - Speed limit
 - Stop lights
 - *“Italian Job”*
- **“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**



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 Follow

- **NFV**

Trends I track : html -> api, ipv4 -> JSON/REST,
dev driven infra, AI in enterprise, infra for
IoT/robotics, hw roots of trust, simplify sec

- **Network programmability & automation**

- **CCIE vs Python (search Internet)**



Future of Networking?

Questions?

