



CS 524

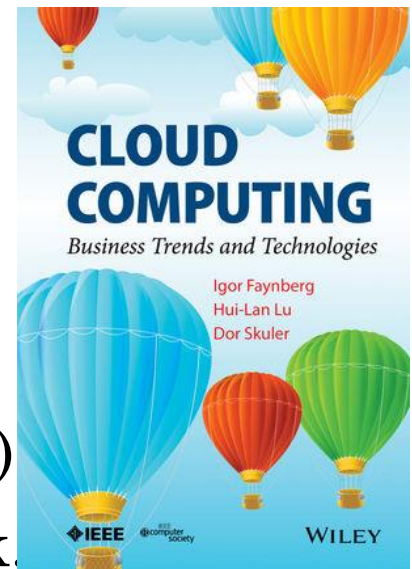
Introduction to Cloud Computing

Module 1: Concept, history, business outlook, definitions, examples, basic building blocks

Igor Faynberg

CS 524 INFORMATION

- Required textbook
- AWS Academy (you will be invited to join)
- Course web site (lecture notes, homework, syllabys policies): *Canvas*
- Write to me: ifaynber@stevens.edu (preferred) or via *Canvas*
- Course assistants:
 - **Sanika Ramchandra Chavan** <schava12@stevens.edu>
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TEACHING METHODOLOGY





DAS GÄNSEBUCH

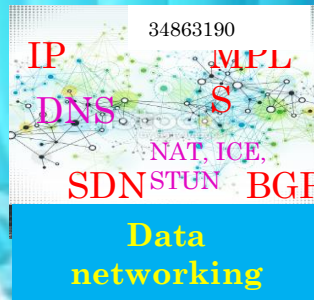


Igor Faynberg
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Introduction to Cloud Computing

Syllabus (an
early cover
design)

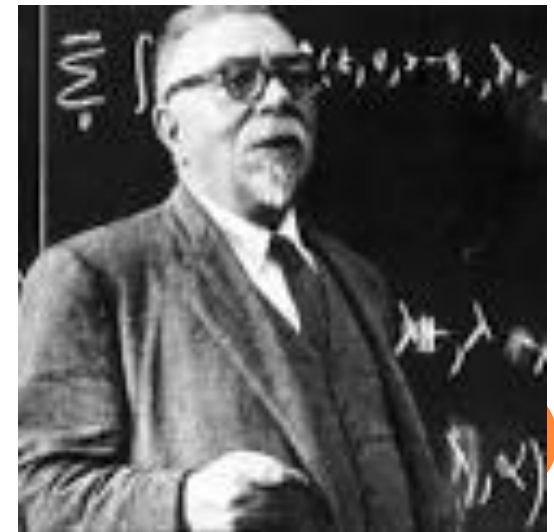


OUTLINE

- What is this all about?
- Business outlook
- Software service models (after Timothy Chou)
- Cloud Economics (an *Amazon* view)
- Evolution
 - Computing: Mainframes, Grid computing, Cloud Computing, Edge Computing, Mist Computing
 - Data Communications: Telecom switches and transmission lines, OSI implementations, Internet, Multi-Protocol Label Switching, software-defined networks, network function virtualization

"If the seventeenth and early eighteenth centuries are the age of clocks, and the later eighteenth and the nineteenth centuries constitute the age of steam engines, the present time is the age of **communication and control.**"

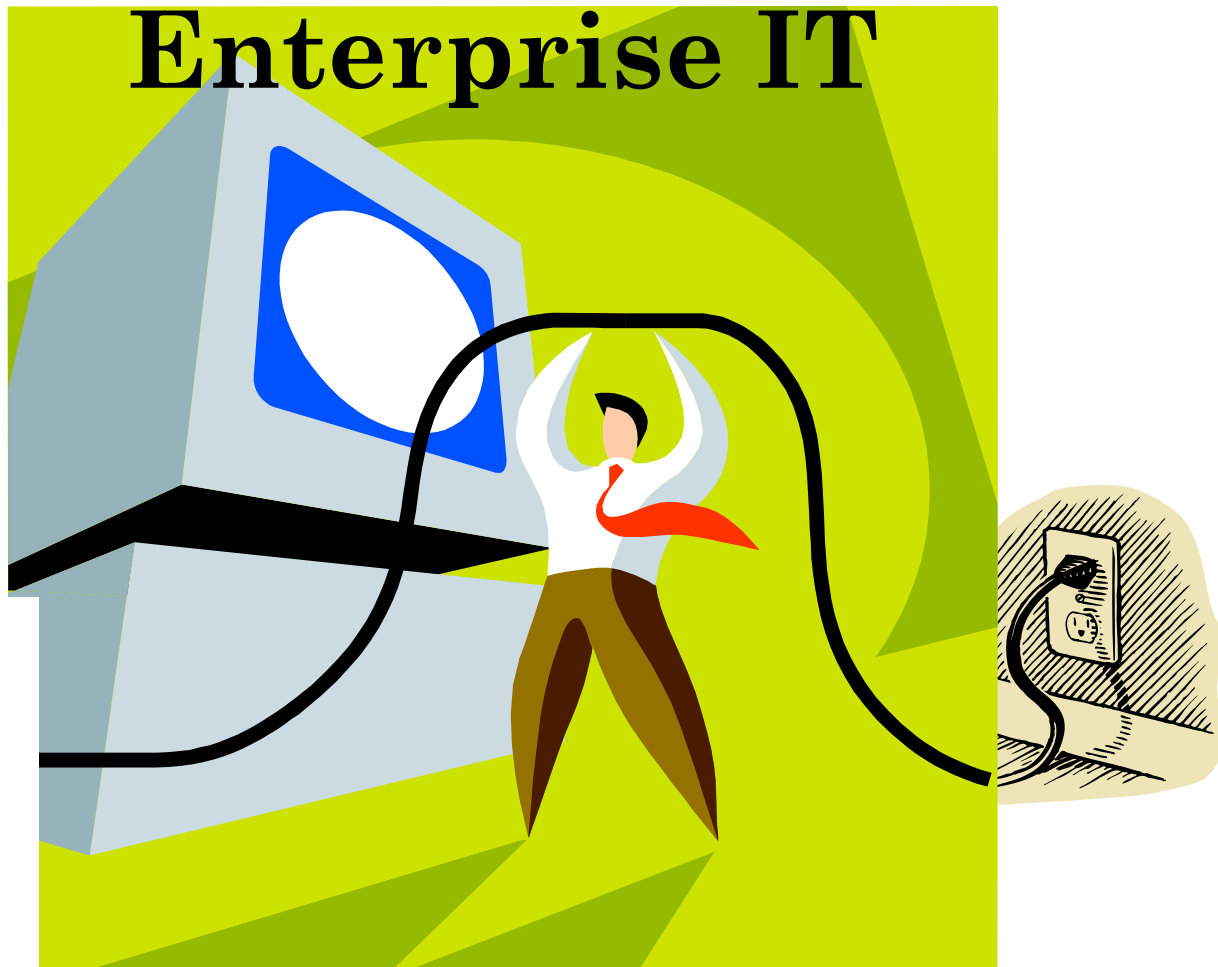
Norbert Wiener, *Cybernetics or Control and Communication of the Animal and the Machine*





The idea of computing as utility to be provided as a service to enterprise was presented in 1994 to Bell Labs by (my thesis advisor and mentor) Professor **Noah Prywes (1905-2020)**.

CLOUD COMPUTING: COMPUTING AS UTILITY



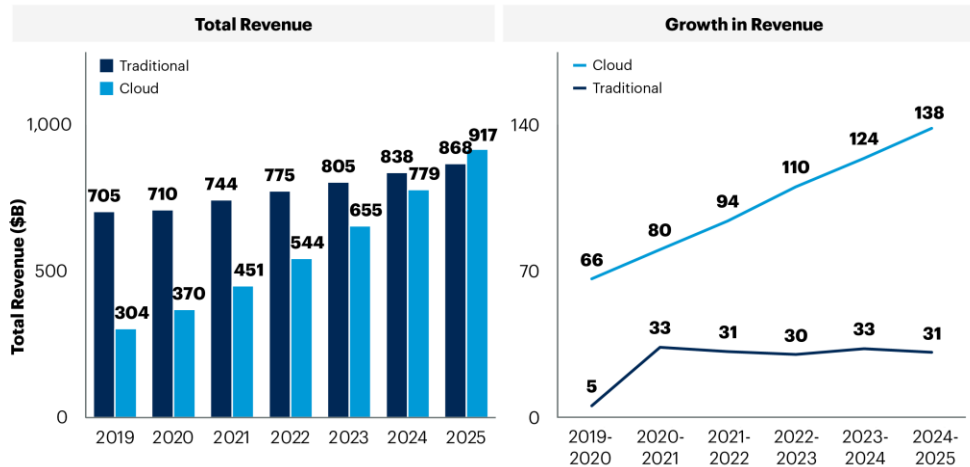
DOUGLAS PARKHILL, THE CHALLENGE OF THE COMPUTER UTILITY, 1966

“A computer utility differs fundamentally from the normal computer service bureau in that the services are supplied directly to the user in his home, factory or office with the user paying only for the service that he actually uses.

The computer utility is a general purpose public system that includes features such as :-

- *Essentially simultaneous use of the system by many remote users.*
- *...*
- *Availability of at least the same range of facilities and capabilities at the remote stations as the user would expect if he were the sole operator of a private computer.*
- *A system of charging based upon a flat service charge and a variable charge based on usage.*
- *Capacity for indefinite growth, so that as the customer load increases, the system can be expanded without limit by various means.”*

Worldwide Public Cloud Services End-User Spending (Millions of U.S. Dollars)



Source: Gartner
758067_C

Gartner 2022 prediction
<https://www.gartner.com/en/newsroom/press-releases/2022-02-09-gartner-says-more-than-half-of-enterprise-it-spending>

PRECEDENCE RESEARCH CLOUD COMPUTING MARKET SIZE, 2021 TO 2030 (USD BILLION)

Gartner.



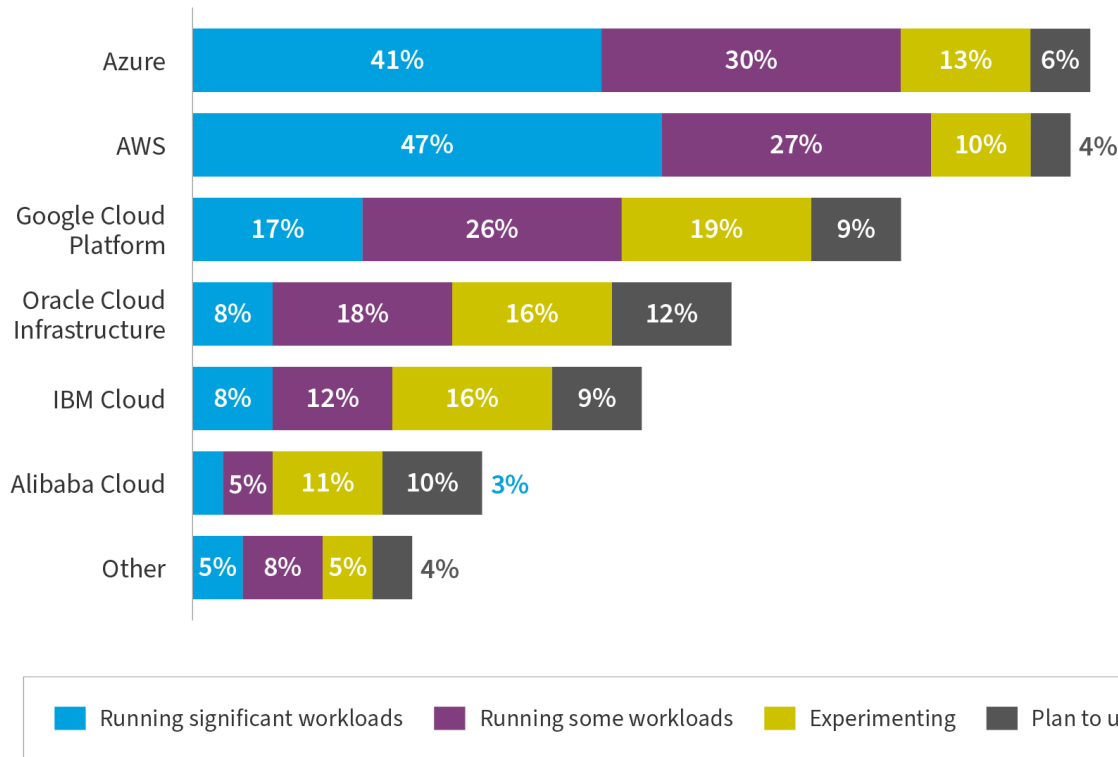
CloudZero 2023 Report:
<https://www.cloudzero.com/blog/cloud-computing-market-size/>

CLOUD PROVIDERS

- Amazon
- Microsoft Azure
- Google
- IBM (acquired Red Hat for about \$34 billion, moves mainframes to Linux)
- Oracle
- Alibaba
- ... Telecom companies to support 5G with Network Function Virtualization (NFV) and Software-Defined Networking (SDN)

...AND THEIR MARKET SHARE

What public cloud providers does your organization use?



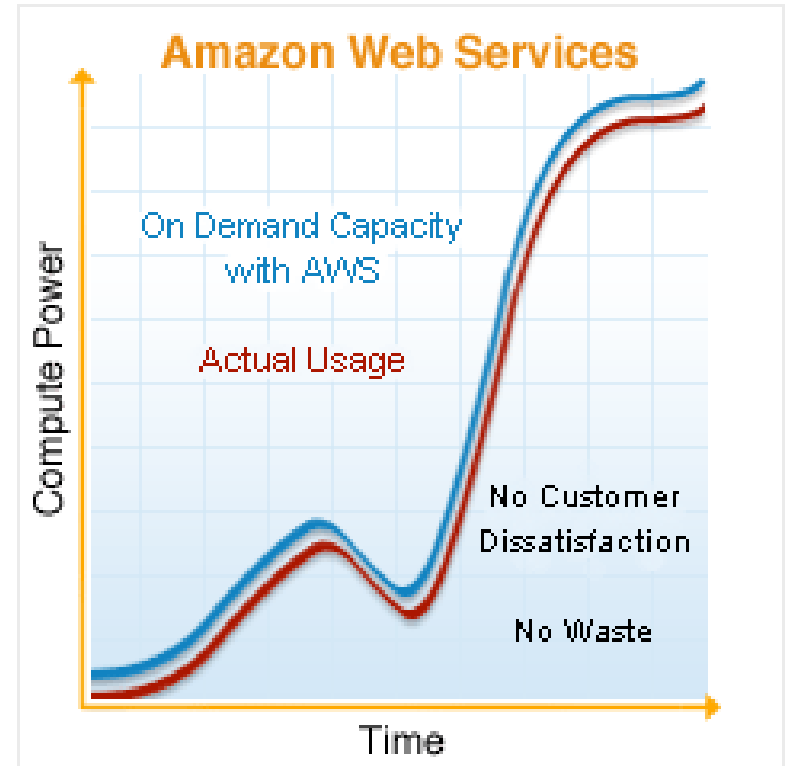
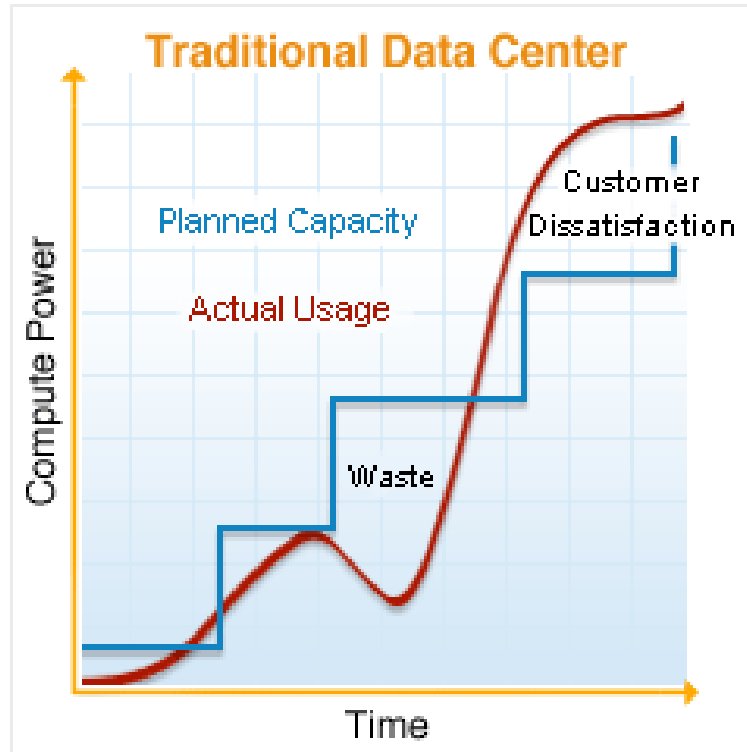
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Source: Flexera 2023 State of the Cloud Report

flexera.



Cloud Economics according to *Amazon*



Source: <http://aws.amazon.com/economics/>

SEVEN SOFTWARE BUSINESS MODELS (AFTER TIMOTHY CHOU)

MODEL 1: TRADITIONAL

- One-time per-user license fee, p
- Perpetual per-year per-user support fee cp , where c is a support ratio coefficient
- Total for the company of n employees over m years:
 $np(1 + mc)$

Of course, for enterprise there is an additional cost of

- a) hardware and
- b) IT salaries

But this business model deems the best for software vendors!
***Microsoft* claims the initial purchase is just 5% of the overall cost of owning the software!**

SEVEN SOFTWARE BUSINESS MODELS (MODEL 2: OPEN SOURCE)

- One-time per-user license fee, 0
- Perpetual per-year per-user support fee f
- Total for the company of n employers over m years: nmf

For enterprise additional costs remain, but theoretically the situation is not **that** different for software vendors

SEVEN SOFTWARE BUSINESS MODELS

(MODEL 3: OUTSOURCING)

- One-time per-user license fee, p
- Perpetual per-year per-user support fee cp , where c is a support ratio coefficient
- (new) service management outsourced to the third party at the per-user per-year cost of s
- Total for the company of n employers over m years:
 $n[p(1 + mc) + ms]$

For enterprise, $s \ll$ cost of doing it itself

The third-party (e.g., *Infosys*) makes profit on *labor arbitrage*

The model is deemed unsustainable long-term

SEVEN SOFTWARE BUSINESS MODELS

(MODEL 4: HYBRID)

- One-time per-user license fee, p
- Perpetual per-year per-user support fee, cp , where c is a support ratio coefficient
- service management is maintained by **the same software vendor** at the per-user per-year cost of s'
- Total for the company of n employers over m years:
 $n[p(1 + mc) + ms']$

For enterprise, $s' < s$ of Model 3!

The vendor (e.g., *Oracle*) is able to deliver better services because of process standardization and automation

The model breaks when all the function can be provided by Model 6

SEVEN SOFTWARE BUSINESS MODELS

(MODEL 5: HYBRID+)

- One-time per-user license fee, **0**
- Perpetual per-year per-user support fee, **including service**, **c**
- Total for the company of **n** employers over **m** years: **nmc**

This just combines the features of Model 2 and Model 4

SEVEN SOFTWARE BUSINESS MODELS

(MODEL 6: SOFTWARE AS A SERVICE)

- One-time per-user license fee, 0
- Perpetual per-year per-user **use fee**, c
- Total for the company of n employers over m years: nmc

Here software is provided as a service (WebEx – an example of a vendor)

**The benefits for enterprise are clear; not so for the vendor
(distribution channel problem)**

SEVEN SOFTWARE BUSINESS MODELS

(MODEL 7: WEB SAAS)

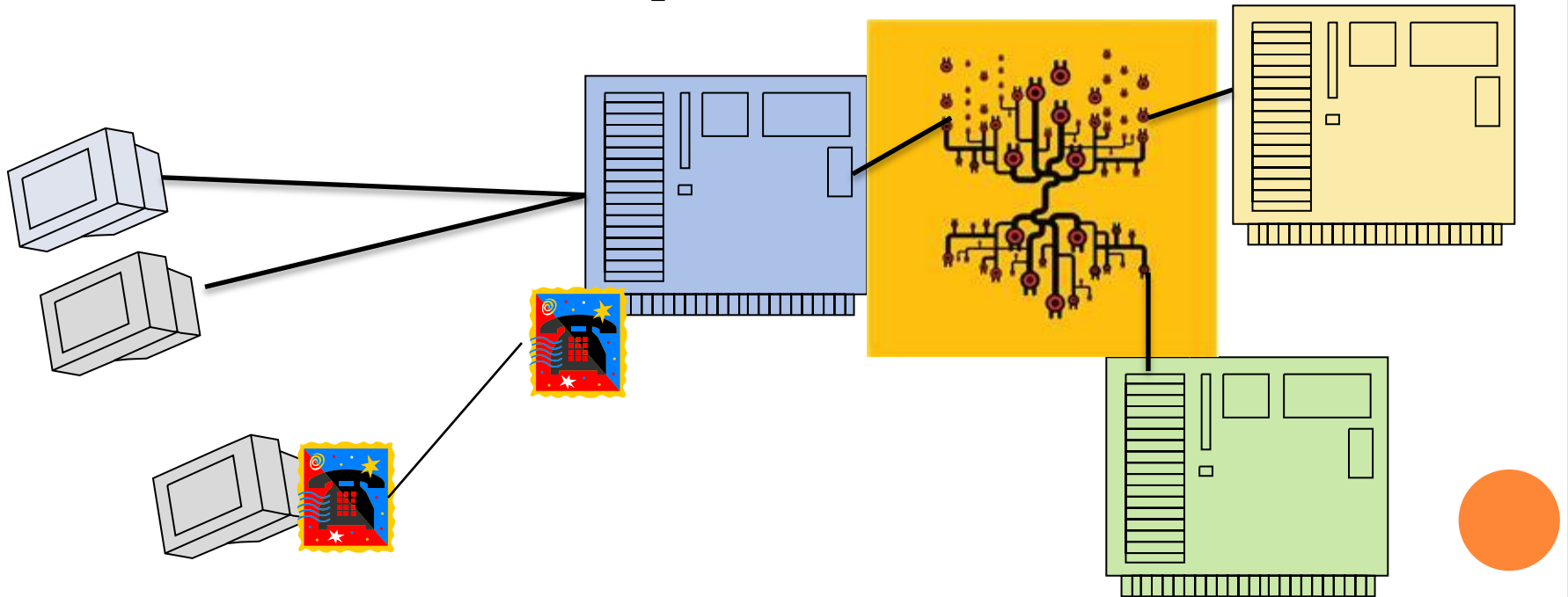
- Subsidized by advertising (adds)
- Provided on-demand
- Free to the user or based on a per-transaction fee
- Based on a specialized solution to a particular problem (search, e-mail, office tools, social networking, entertainment)

Strings attached: The actual product sold is user's personal information

Works well in the world where advertisement is essential

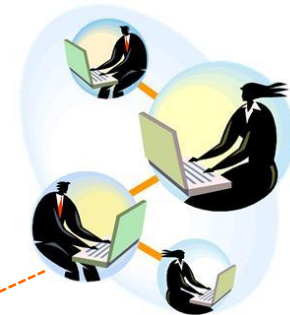
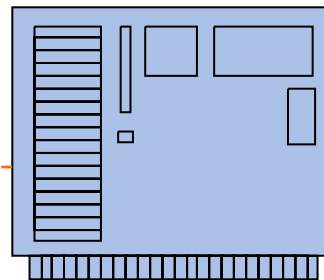
HISTORY: MAINFRAME COMPUTING (1970s-1980s)

- Directly-connected terminals (*dumb* and *smart*)
- Teletype terminals connected over telephone lines
- Interconnection over *private* data networks



HISTORY: PC COMPUTING (1990-PRESENT)

- Can work independently
- Can act as a terminal to a mainframe
- Can interconnect via Local Area Network (LAN)
- Can interconnect via Internet

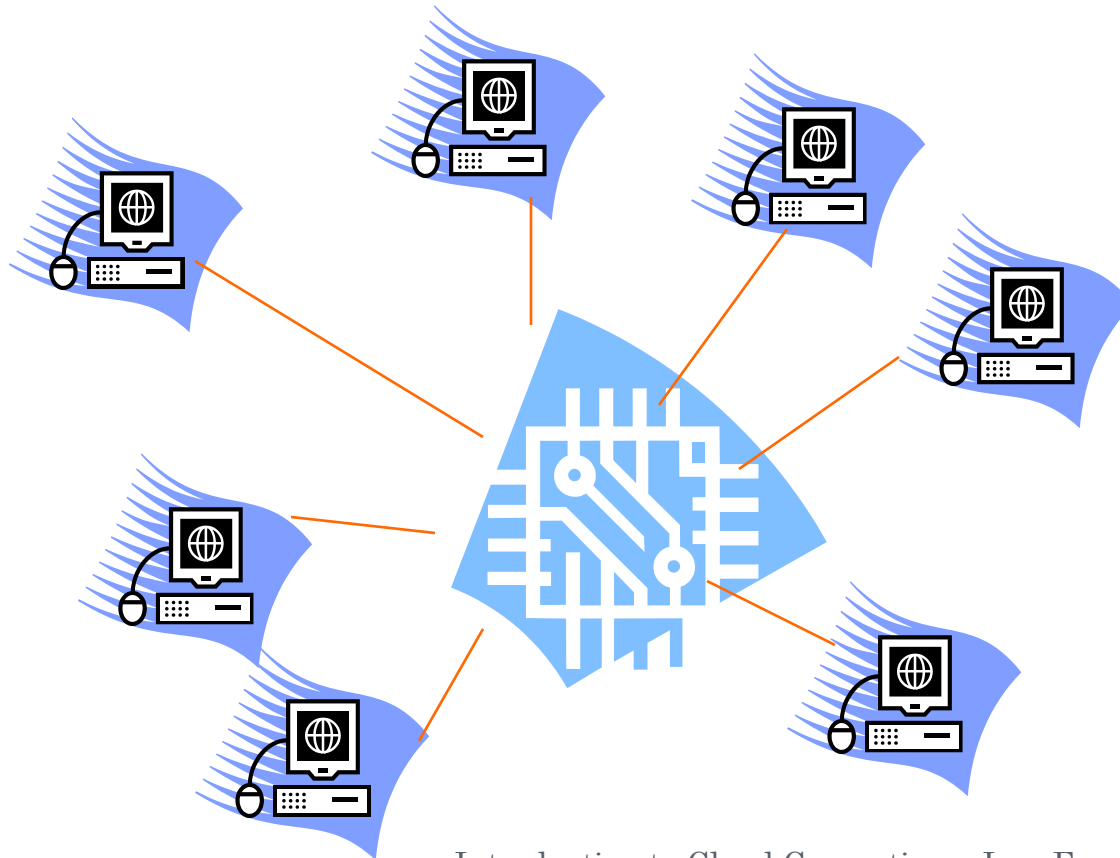


HISTORY: GRID COMPUTING (1990s – PRESENT)

A form of *distributed computing*, with the aim of creating a virtual supercomputer

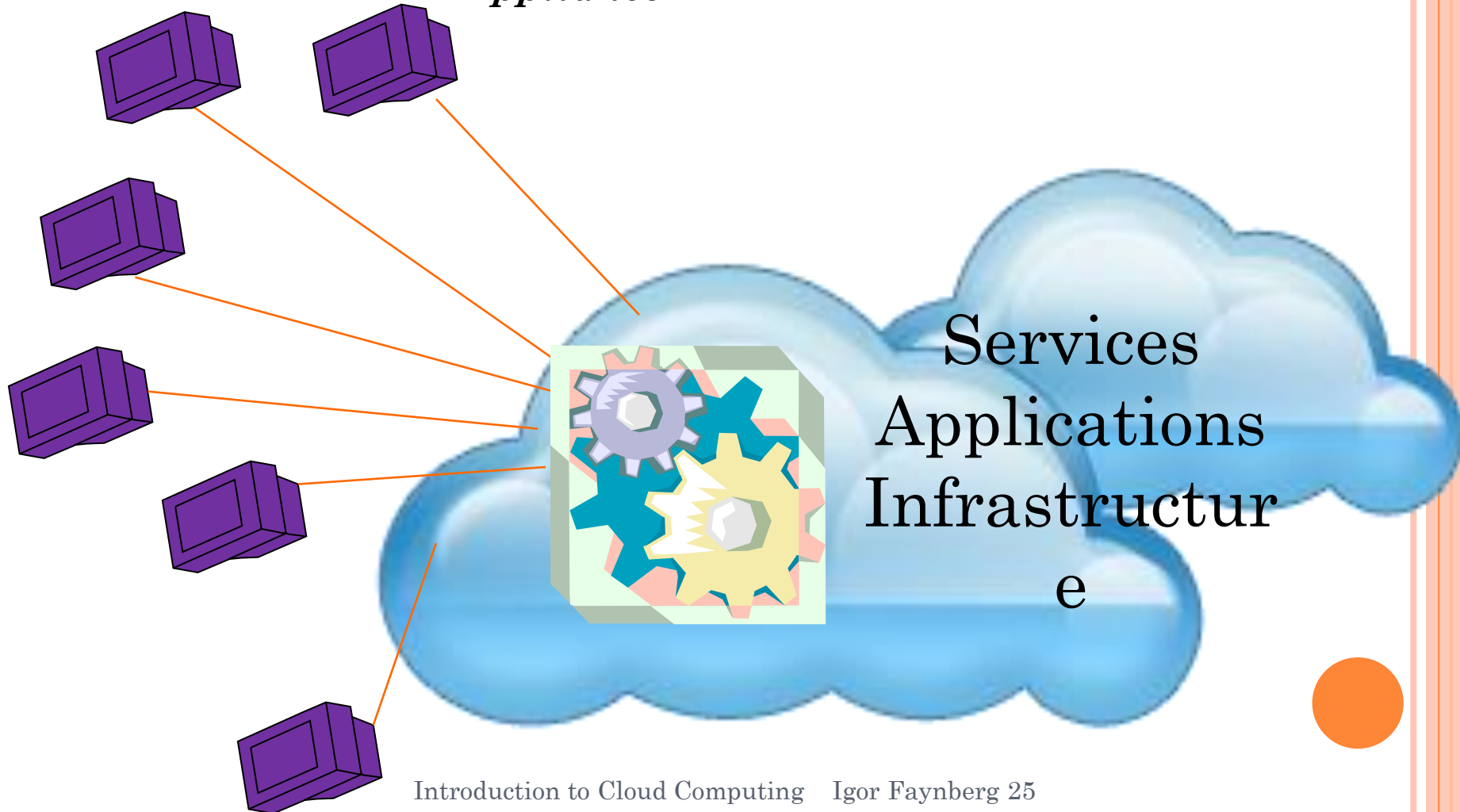
See: R .Buyya and S. Venugopal: *A Gentle Introduction to Grid Computing and Technologies*

www.buyya.com/papers/GridIntro-CSI2005.pdf

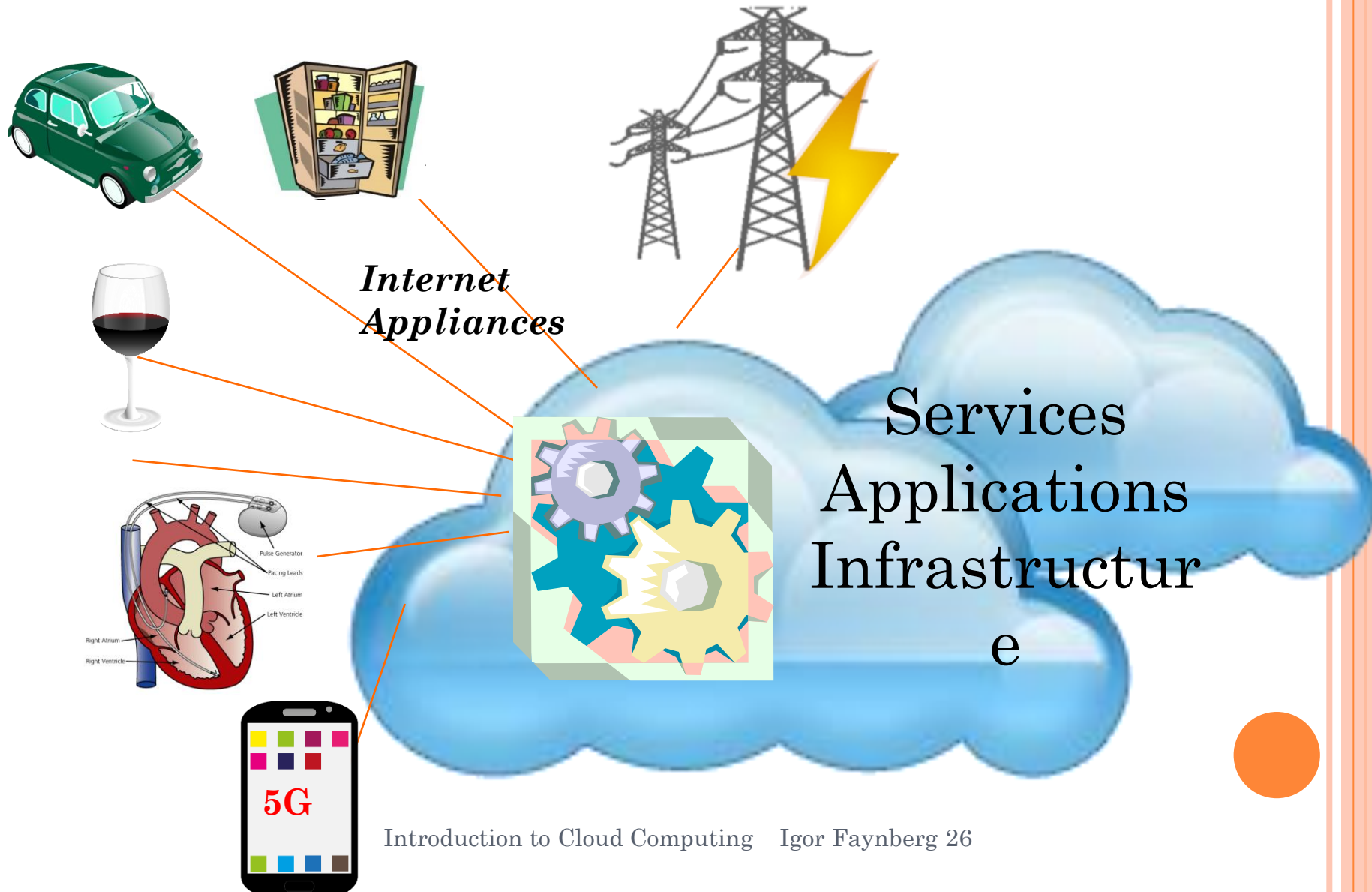


HISTORY: CLOUD COMPUTING (2000s)

*Internet
Appliance*



HISTORY: CLOUD COMPUTING AND THE INTERNET OF THINGS (IOT) (2010-PRESENT)

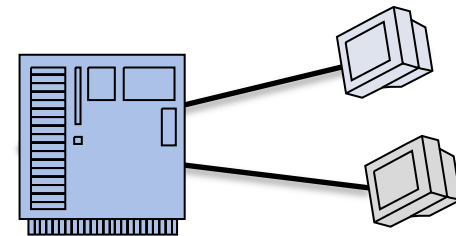
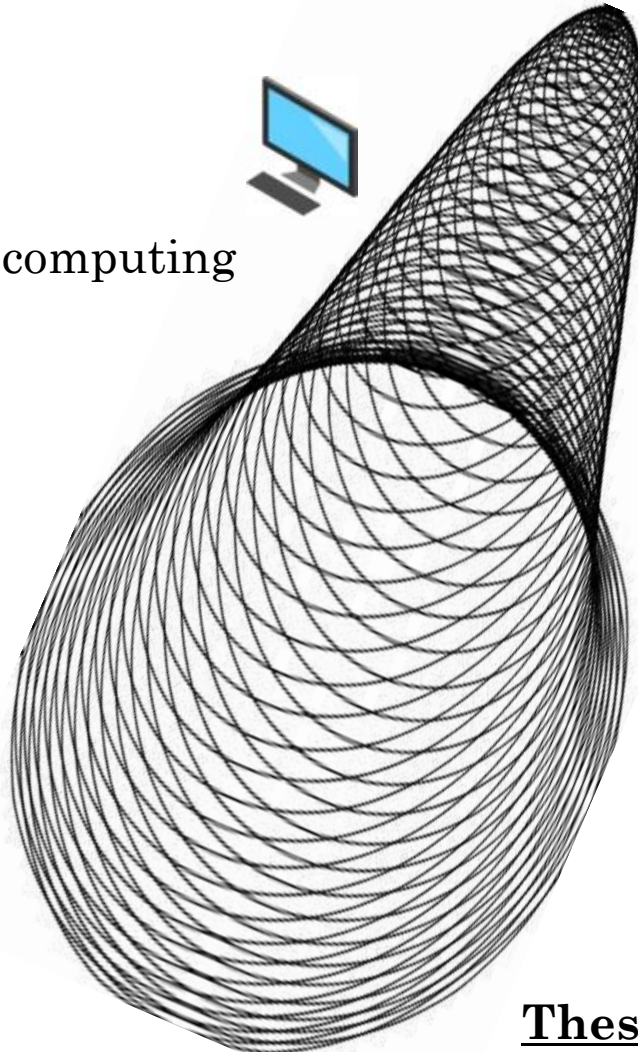


TIME TO STEP BACK: HEGELIAN DIALECTIC AT WORK

Antithesis: PC computing



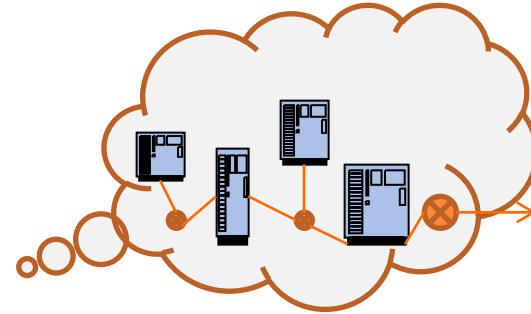
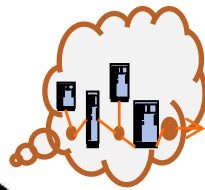
Synthesis: Cloud computing



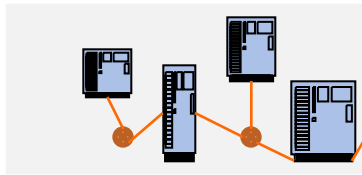
Thesis: Mainframe computing



Synthesis
Enterprise IT
Private Cloud



Antithesis: Public Cloud



Thesis: Enterprise IT
data center

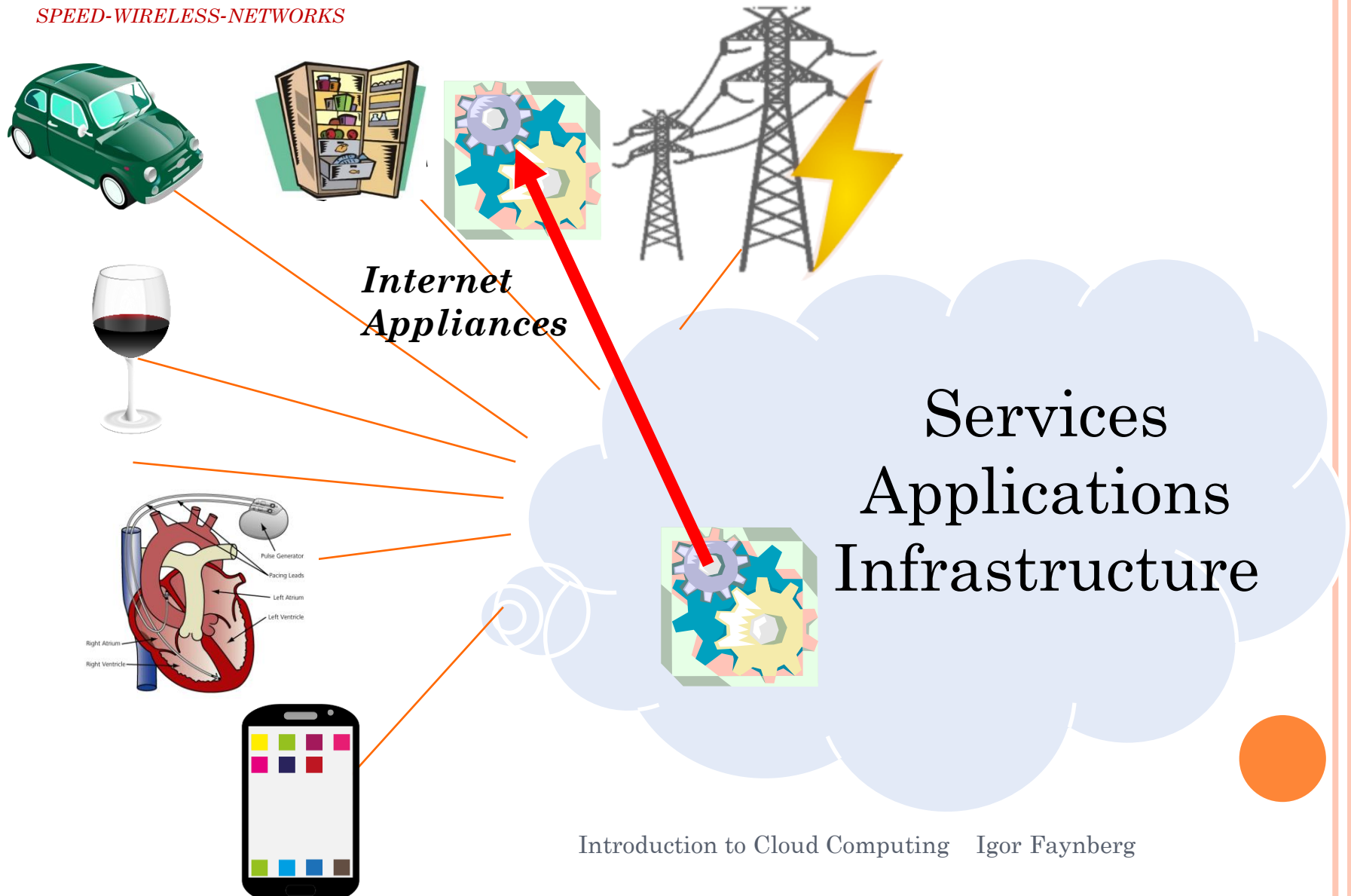
From IT data center to Private Cloud



BUT THIS IS NOT THE END OF EVOLUTION!

MEET *FOG* COMPUTING

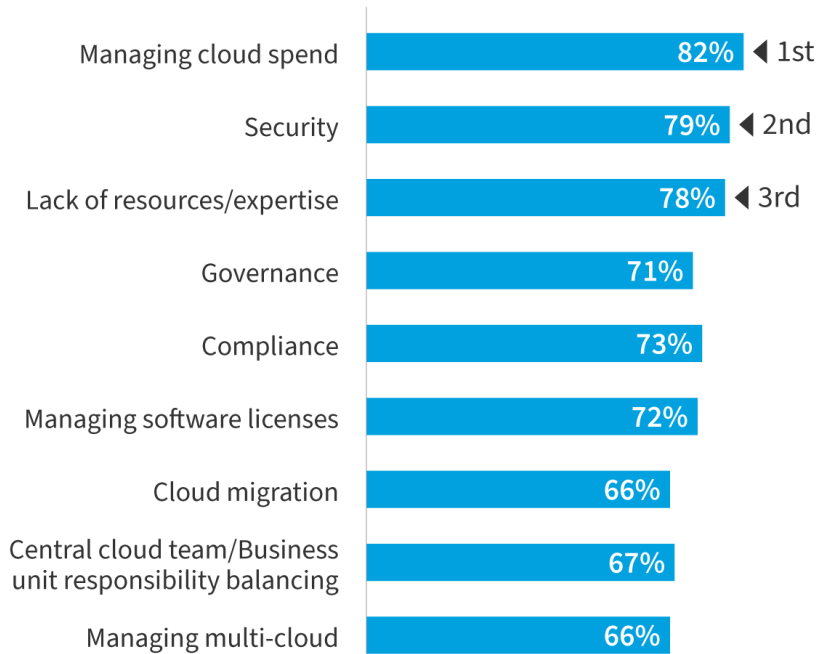
[HTTPS://WWW.PRINCETON.EDU/NEWS/2015/12/16/FOG-COMPUTING-HARNESSES-PERSONAL-DEVICES-SPEED-WIRELESS-NETWORKS](https://www.princeton.edu/news/2015/12/16/fog-computing-harnesses-personal-devices-speed-wireless-networks)



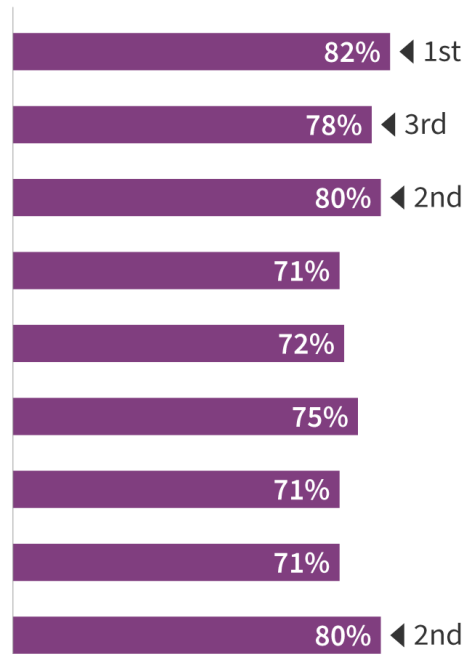
WHERE CAN WE CONTRIBUTE?

Top cloud challenges

All organizations



Enterprise



SMB (Small and medium businesses)

