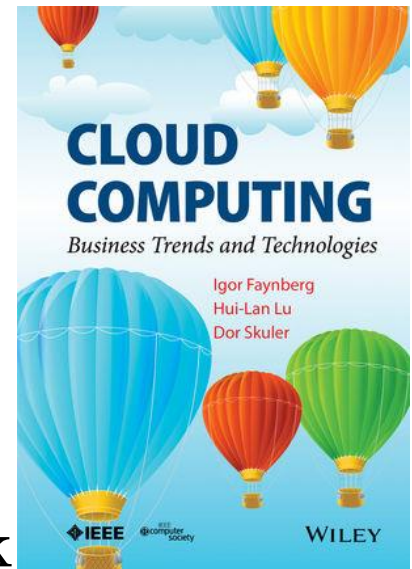# CS 524

Introduction to Cloud Computing

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

Igor Faynberg

CS 524 Information

- Required textbook

- Course web site (lecture notes, homework, policies): *Canvas*

- Write to me: ifaynber@stevens.edu (preferred) or via *Canvas*

- Course assistant:

  Sumit Gupta (*sgupta34@stevens.edu*)
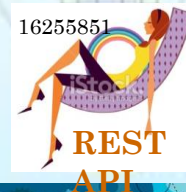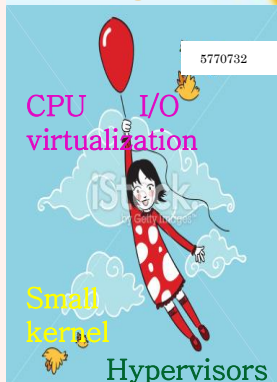
TEACHING METHODOLOGY

DAS GÄNSEBUCH_T

Igor Faynberg
Hui-Lan Lu
Dor Skuler

29506128

Syllabus (an early cover design)

Introduction to Cloud Computing

OpenStack

Orchestration

34863190

IP
DNS
MPLS
NAT, ICE,
SDN STUN BGP
Data networking

36476654

Operations and Management

22587013

iSCSI
SAN
Storage

44377830

Security

16255851

REST API

SNMP
COPS
NETCONF TOSCA

5770732

CPU I/O
virtualization

NAS 50326746
DAS
Data Center

25736551

Business aspects

Public Cloud

Private Cloud

NFV

"Shadow IT"

Small kernel

Hypervisors

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 eighteens 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."
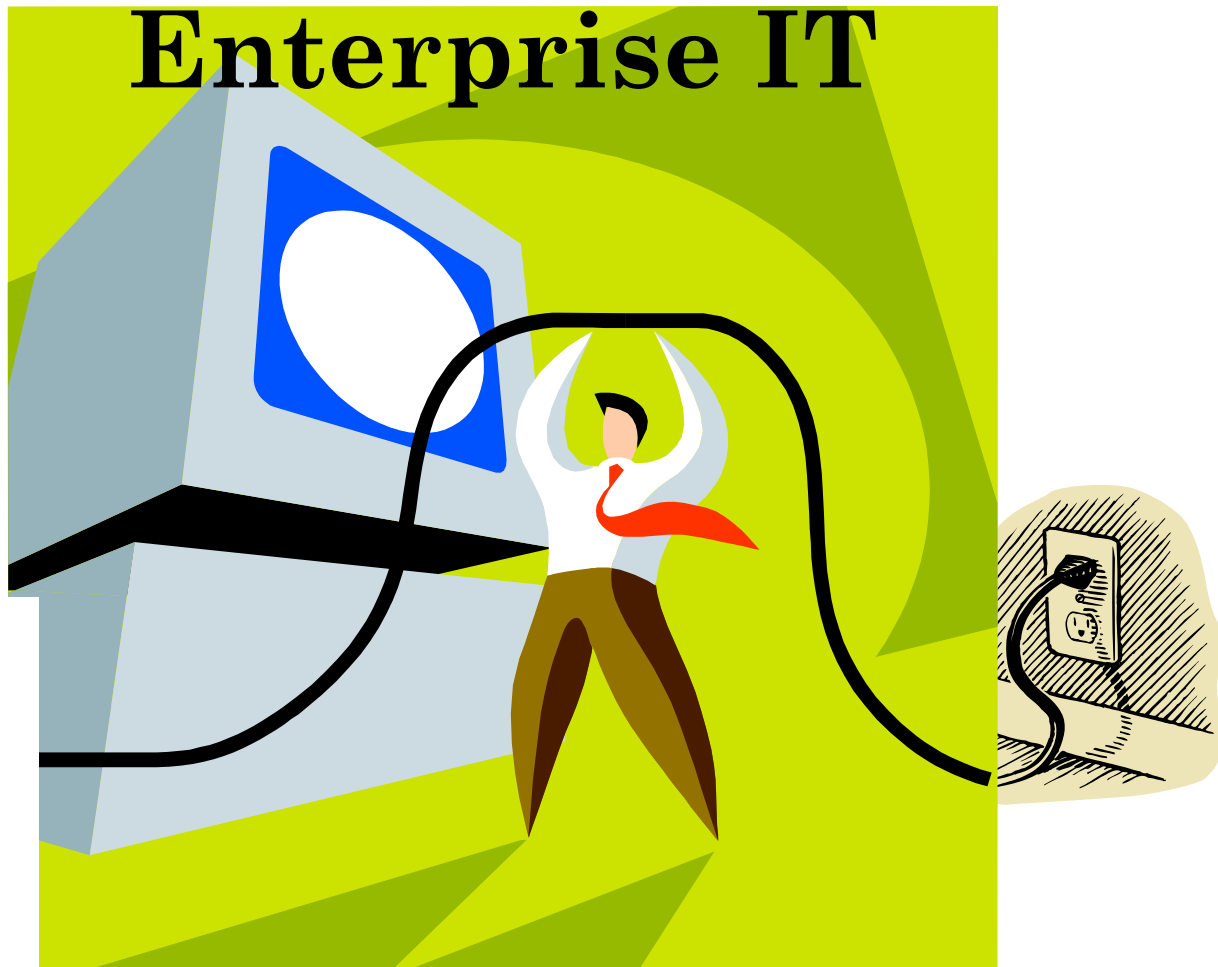
Norbert Wiener, Cybernetics or Control and Communication of the Animal and the Machine
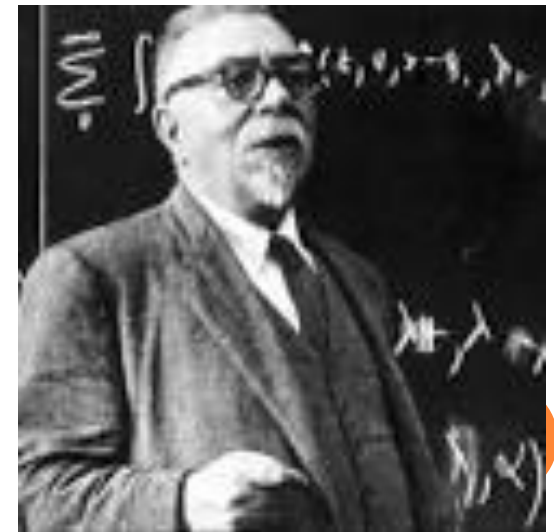
The idea of computing as utility to be provided as a service to enterprise was presented to Bell Labs by (my thesis advisor) Professor Noah Prywes in 1994.

CLOUD COMPUTING: COMPUTING AS UTILITY

Enterprise IT

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 where 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 expanded without limit by various means."*

Igor Faynberg

Business outlook

Public IT Cloud Spending ($Billions)
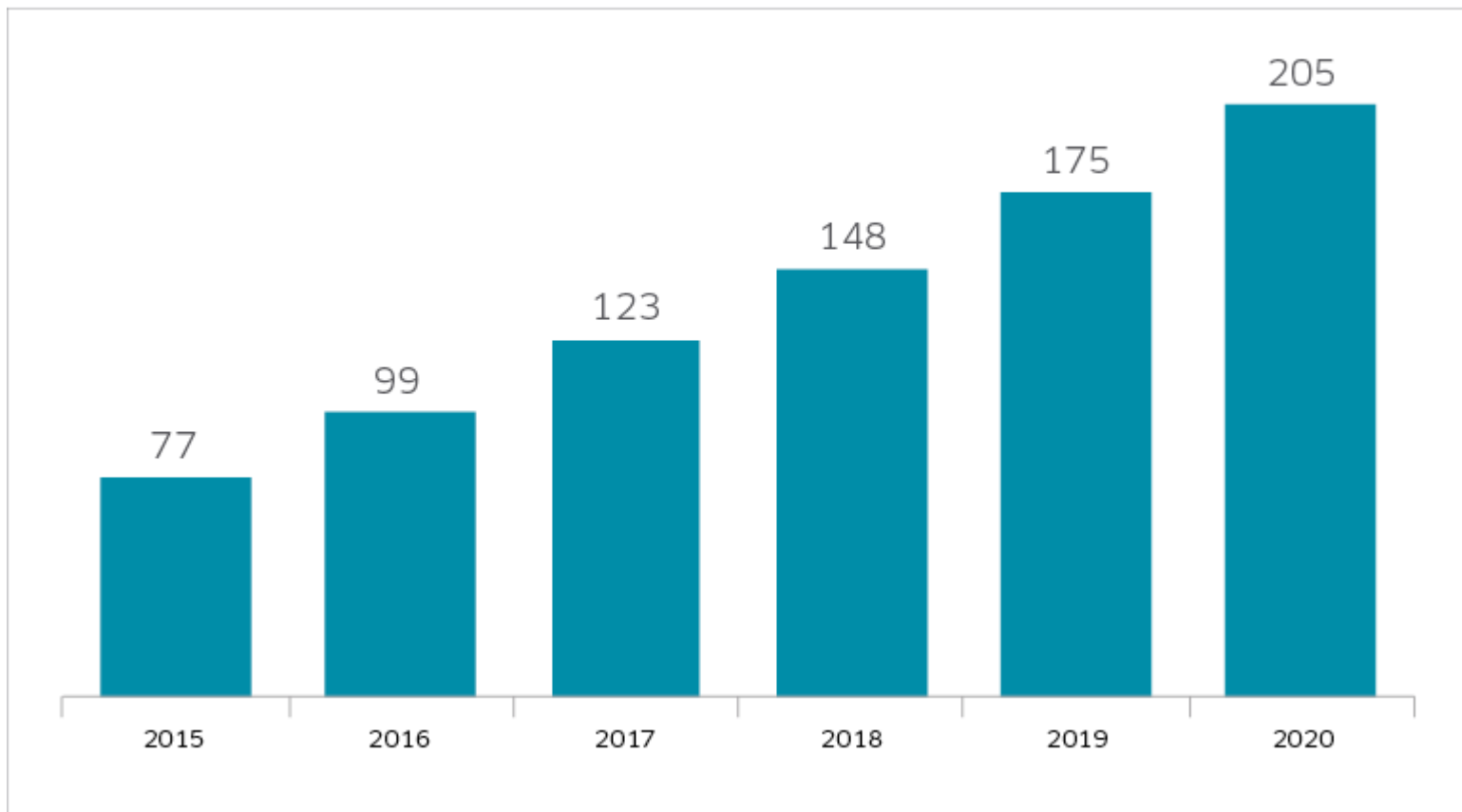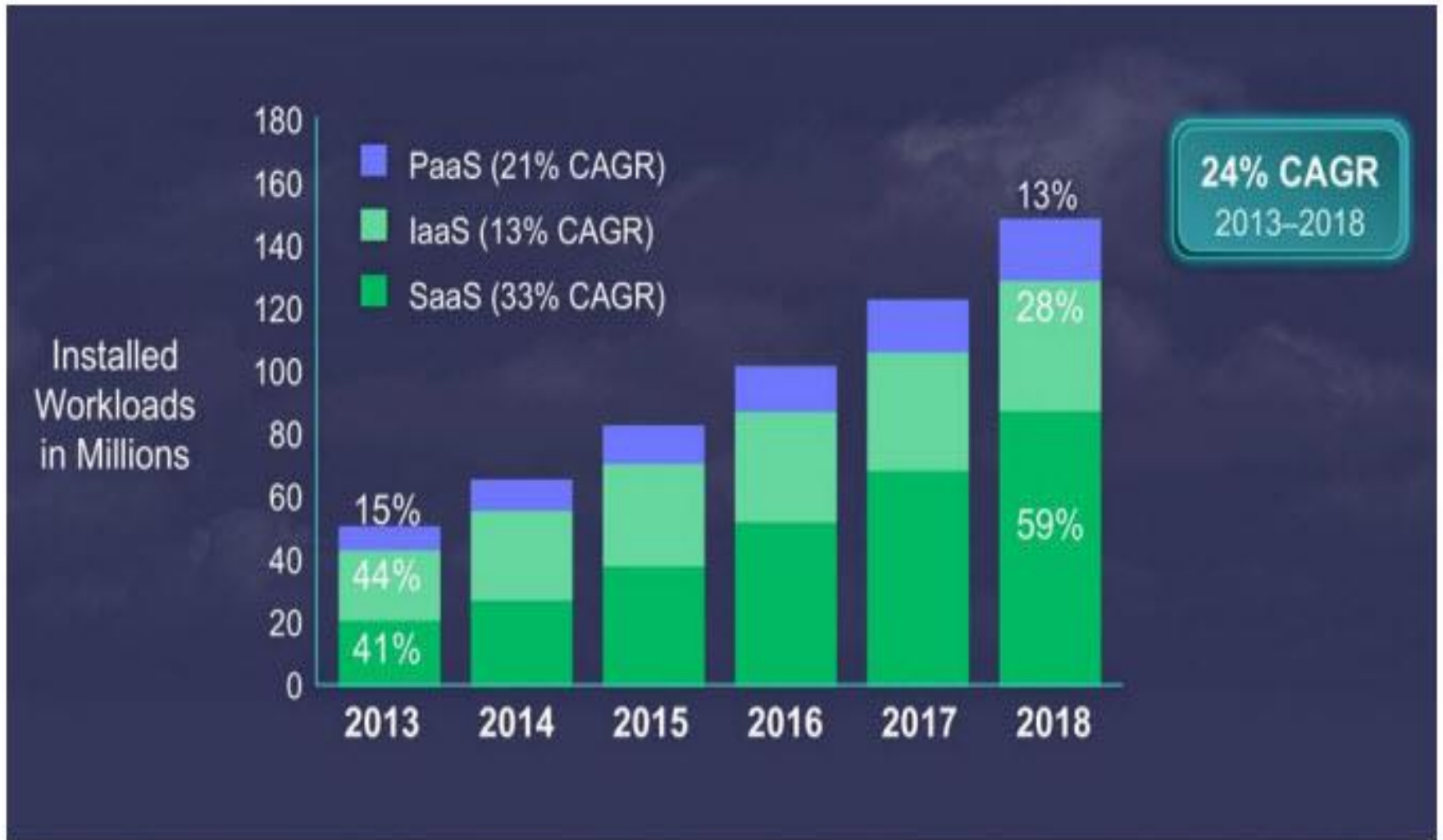
Source: Cisco Global Cloud Index, 2013–2018

The **compound annual growth rate (CAGR)** is a measure of growth over multiple time periods assuming the investment has been compounding.

Forecast: Global Public Cloud Market Size, 2011 To 2020

The spreadsheet detailing this forecast is available online.

	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

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Source: Forrester Research, Inc.

PLAYERS IN CLOUD: CLOUD PROVIDERS

- Amazon
- 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)

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Cloud Economics according to *Amazon*

Source: http://aws.amazon.com/economics/
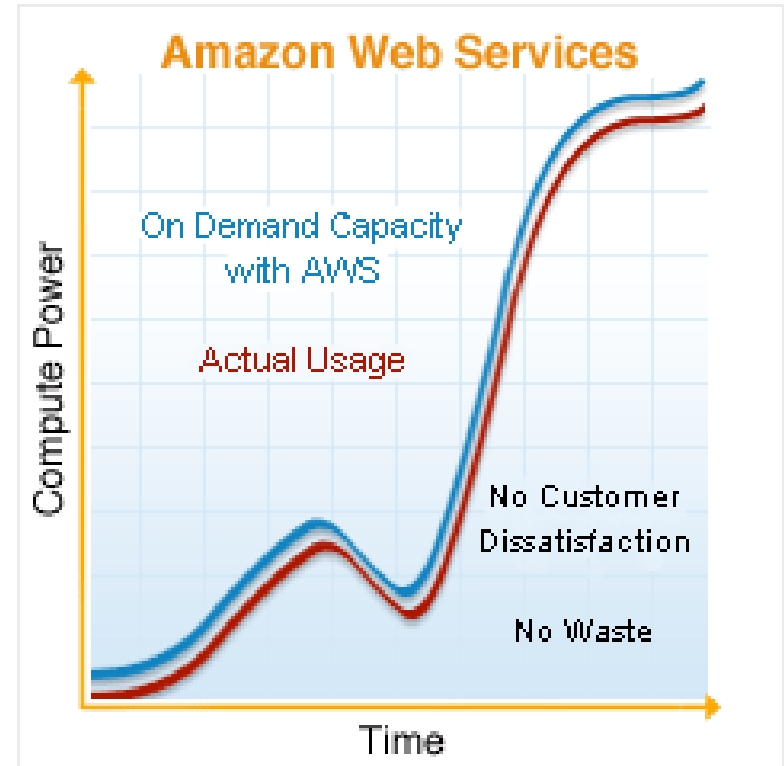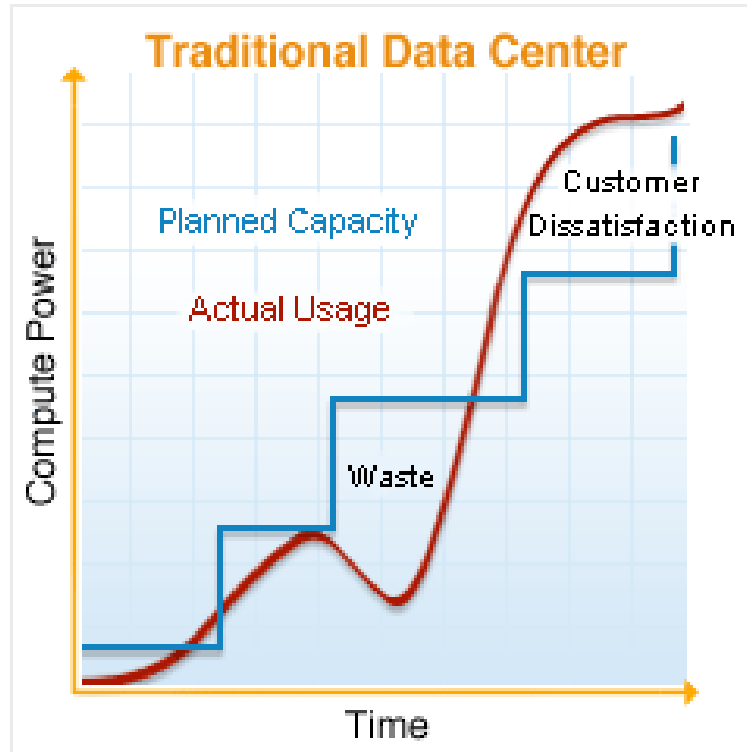
Seven Software Business Models
(after Timothy Chou)
Model 1: Traditional

- 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, <u>for enterprise </u> 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

<u>For enterprise</u> 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 << 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 <u>user's personal information</u>

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
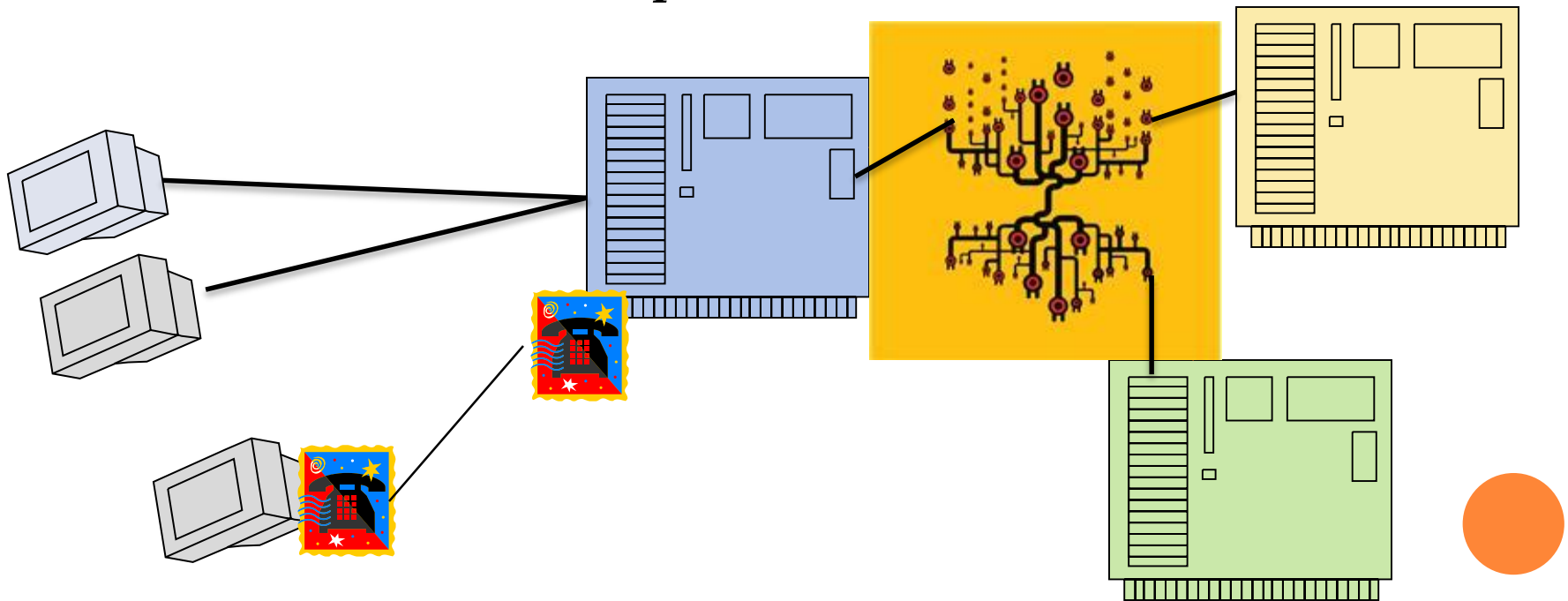
HISTORY: PC COMPUTING (1990-PRESENT)

o Can work independently

o Can act as a terminal to a mainframe

o Can interconnect via Local Area Network (LAN)

o Can interconnect via Internet
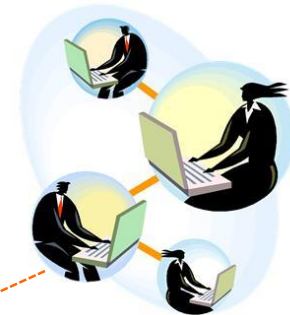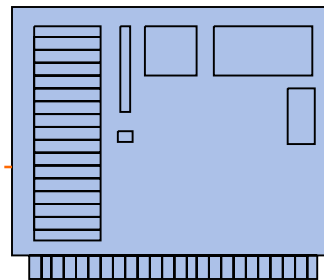
HISTORY: GRID COMPUTING (1990S – PRESENT)
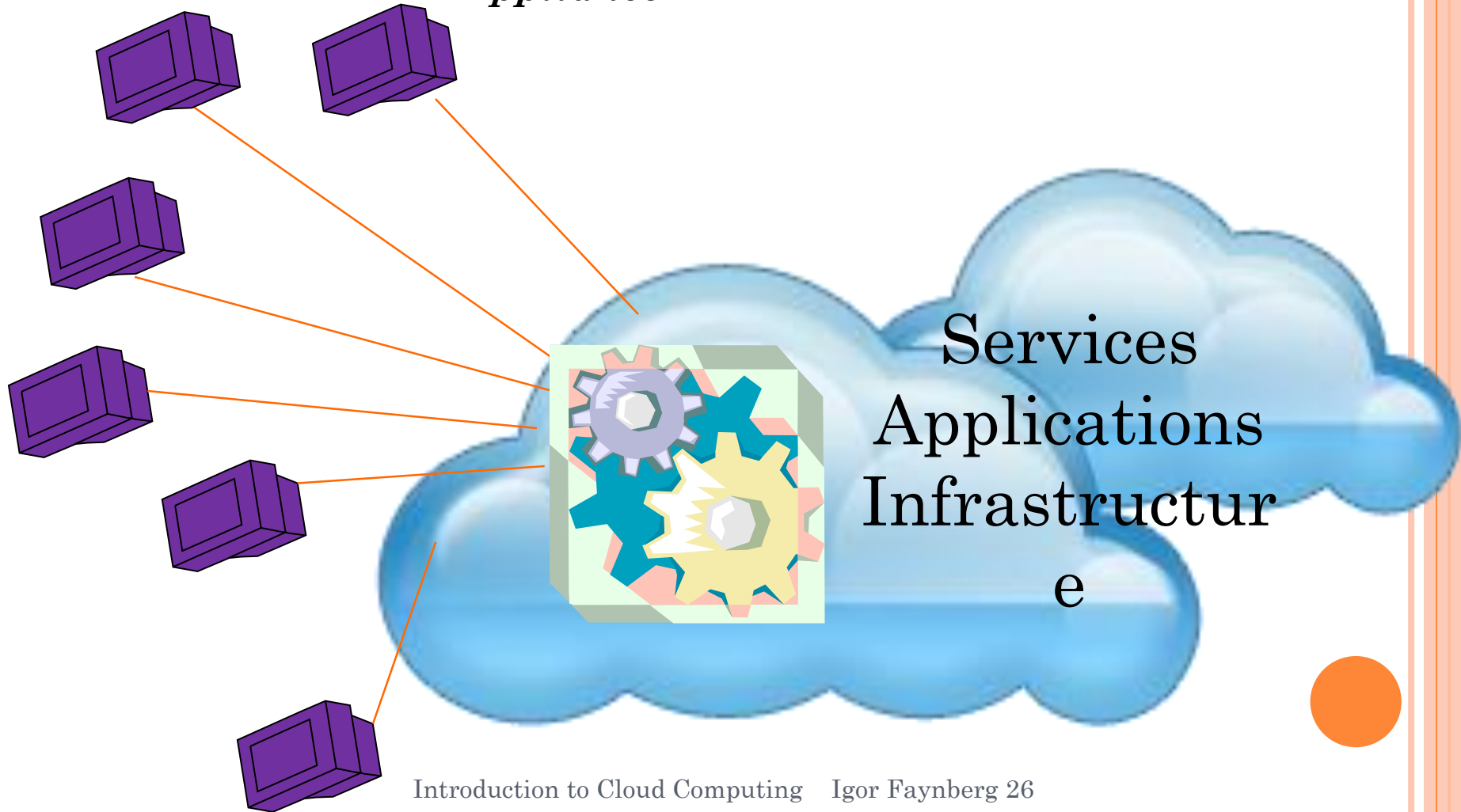
A form of *distributed computing,* with the aim of creating a virtual supercomputer

See: R .Buyya and S. Venugopal: *A Gentle Introduction to Grid Computing and Technologies*
www.buyya.com/papers/GridIntro-CSI2005.pdf
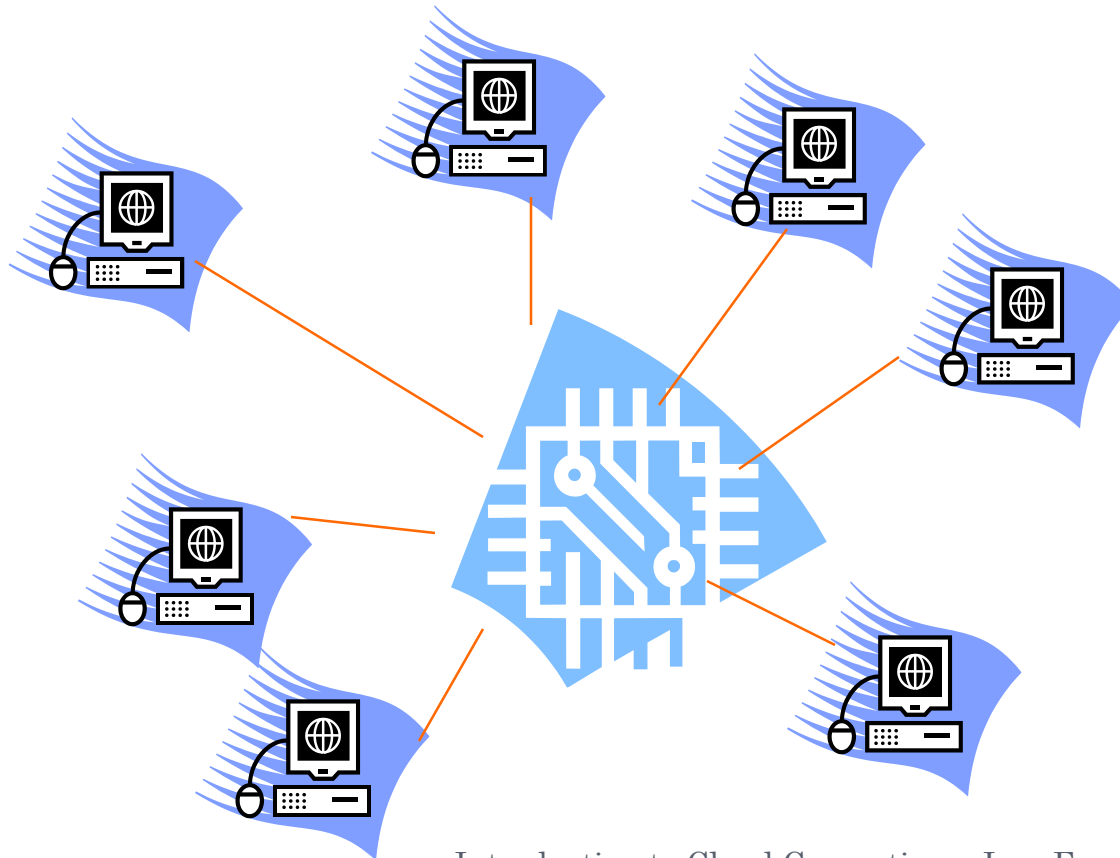
HISTORY: CLOUD COMPUTING (2000S)

Internet Appliance

Services
Applications
Infrastructure

Internet Appliances

Services
Applications
Infrastructure

5G
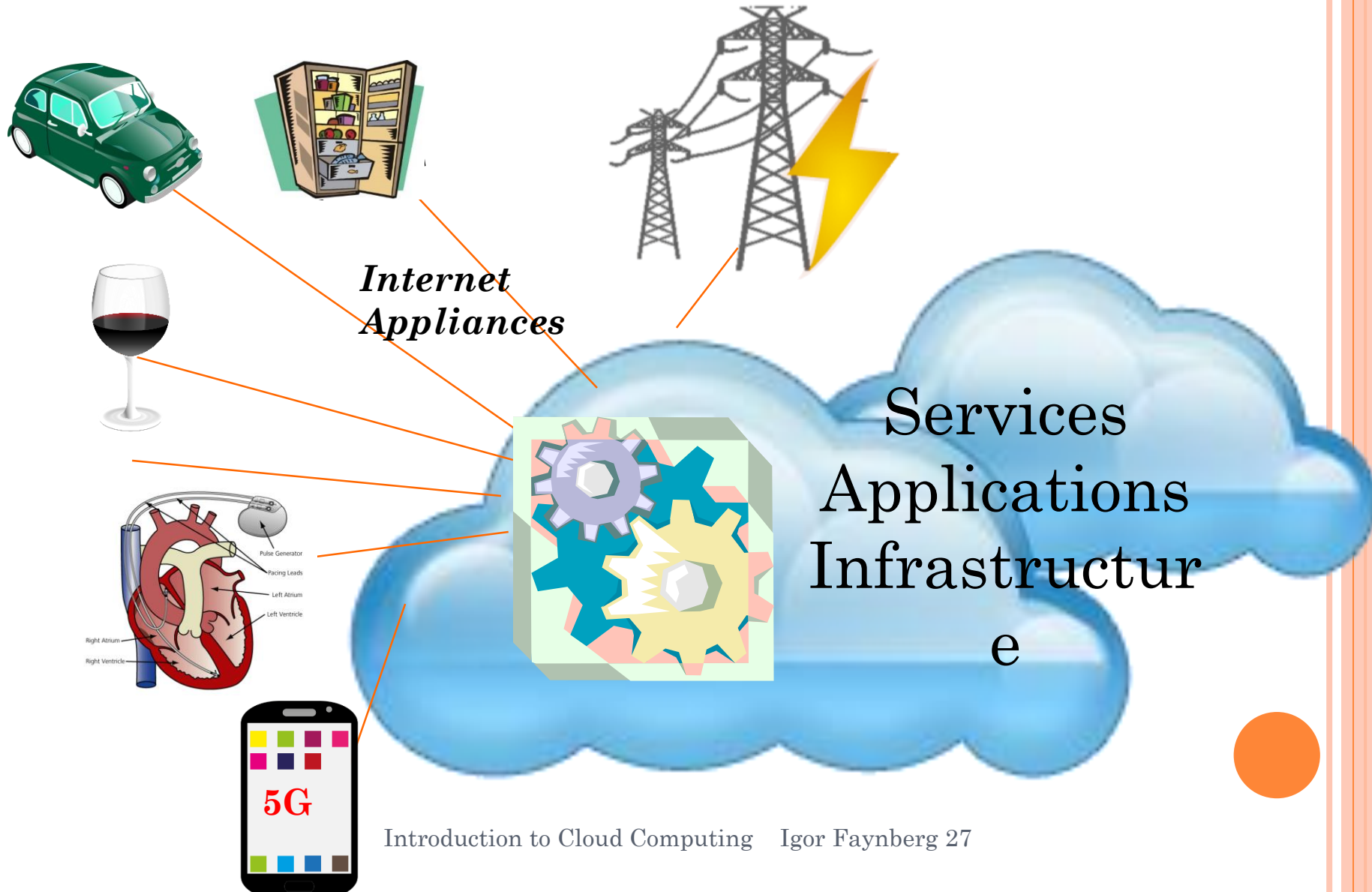
TIME TO STEP BACK:
HEGELIAN DIALECTIC AT WORK
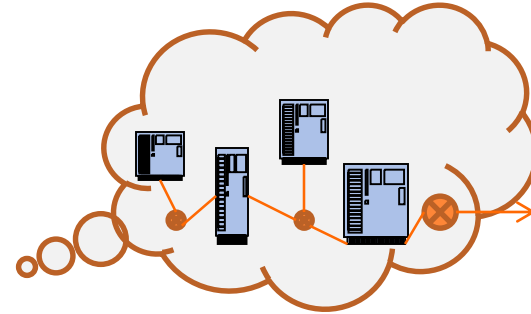
Synthesis: Cloud computing
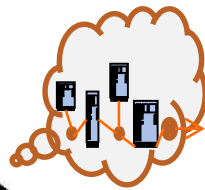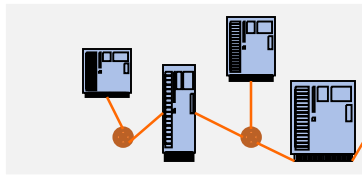
Antithesis: PC computing
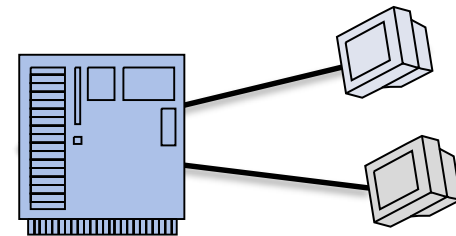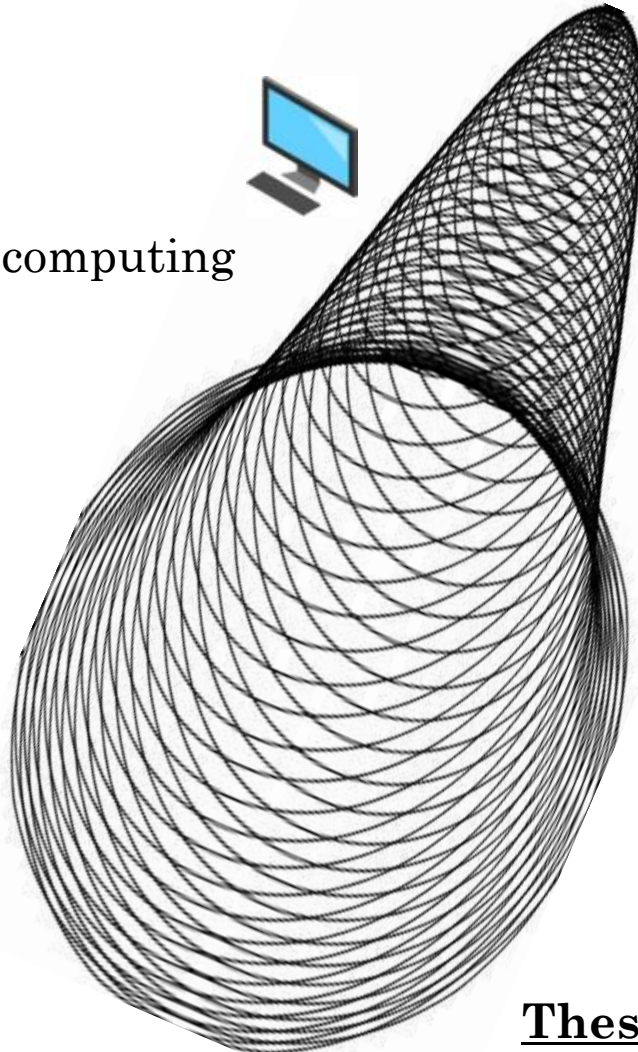
Thesis: Mainframe computing

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

Internet Appliances

Services
Applications
Infrastructure