Cyber-Physical Systems … Who Cares?

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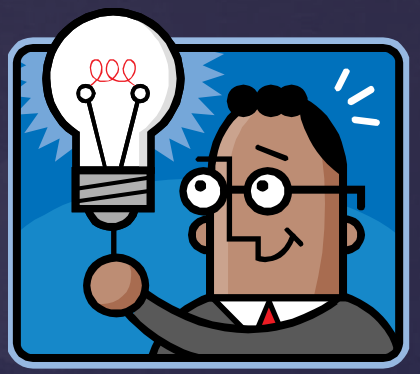
Most people don’t care about most technologies…



But, once a while, a truly disruptive technology comes along …

It makes certain natural or societal resources commodity

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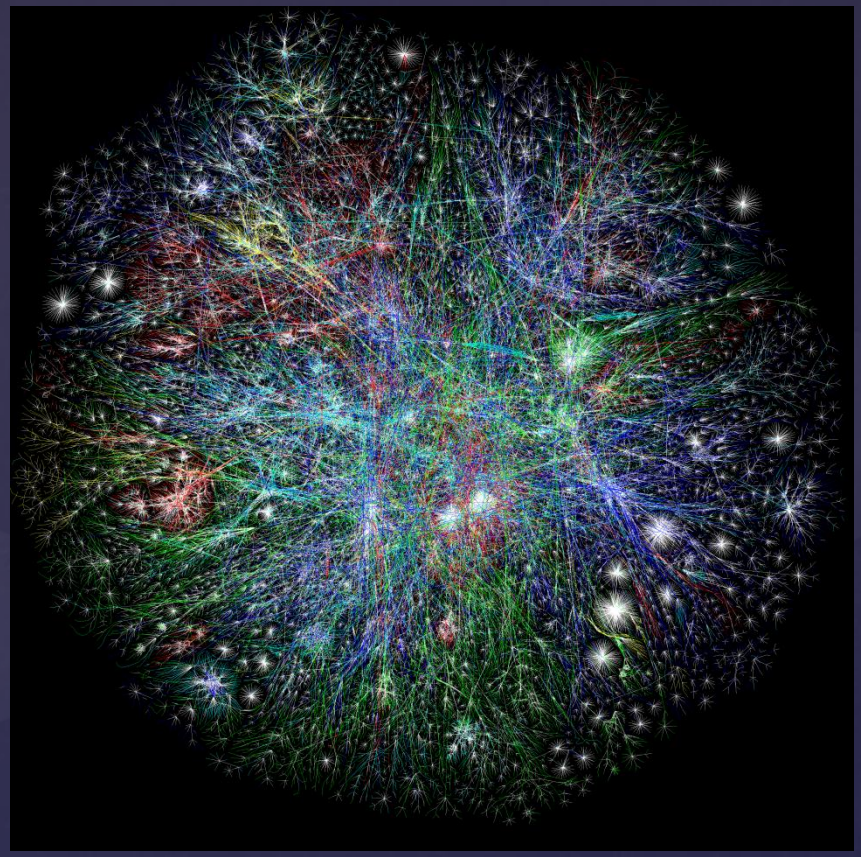


It makes certain natural or societal resources commodity

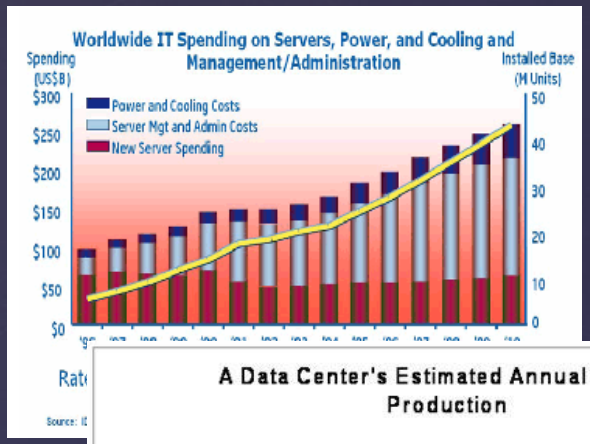
And younger generations couldn’t believe there were life without it…

Are cyber-physical systems disruptive?

Or are they repackaging known technologies and making them a little better?

A Data Center Example

Energy Hog


Worldwide IT Spending on Servers, Power, and Cooling and Management/Administration
Spending (US$B)
Installed Base (M Units)
Power and Cooling Costs
Server Mgt and Admin Costs
New Server Spending


RATIO OF 3-YEAR SITE COSTS (OpEx + CapEx) TO 1U SERVER COSTS
Continuation of Actual
Projection A
Projection B
Actual
Year Ending

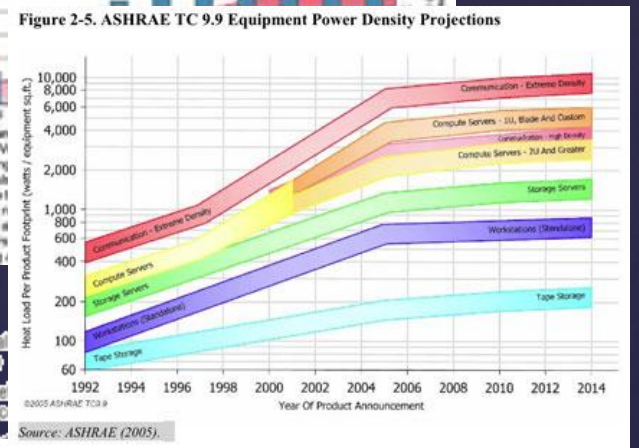
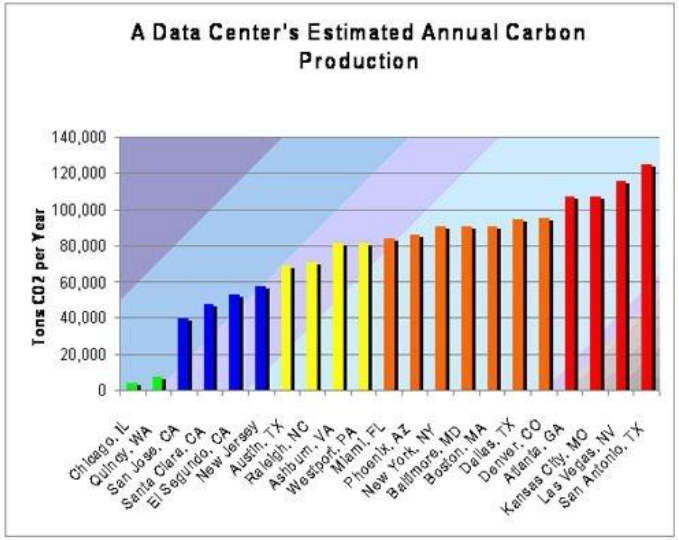
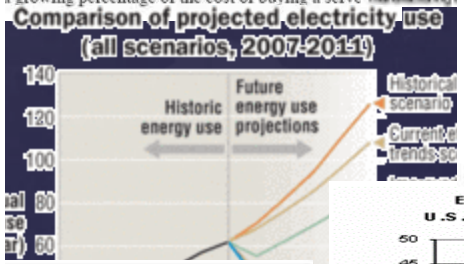
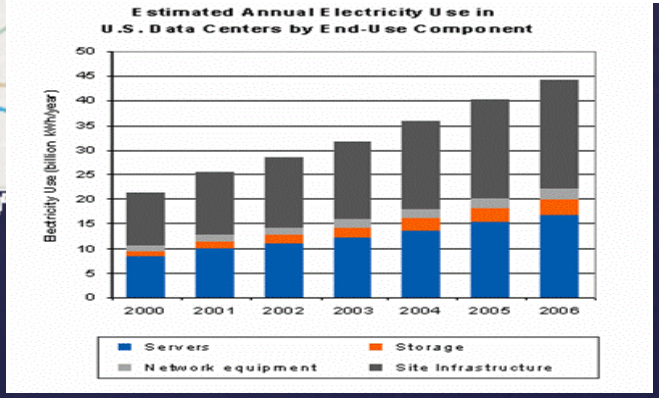
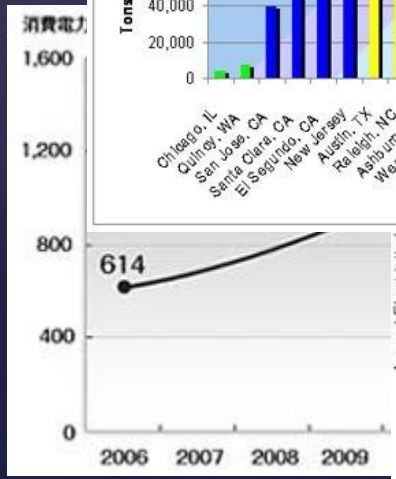


Figure 2-5. ASHRAE TC 9.9 Equipment Power Density Projections
Heat Load Per Product Footprint (watts / equipment sq.ft.)
Year Of Product Announcement
Source: ASHRAE (2005).


A Data Center's Estimated Annual Carbon Production
Tons CO2 per Year


Comparison of projected electricity use (all scenarios, 2007-2011)
Historic energy use
Future energy use projections


Estimated Annual Electricity Use in U.S. Data Centers by End-Use Component
Electricity Use (billion kWh/year)
Servers
Storage
Network equipment
Site Infrastructure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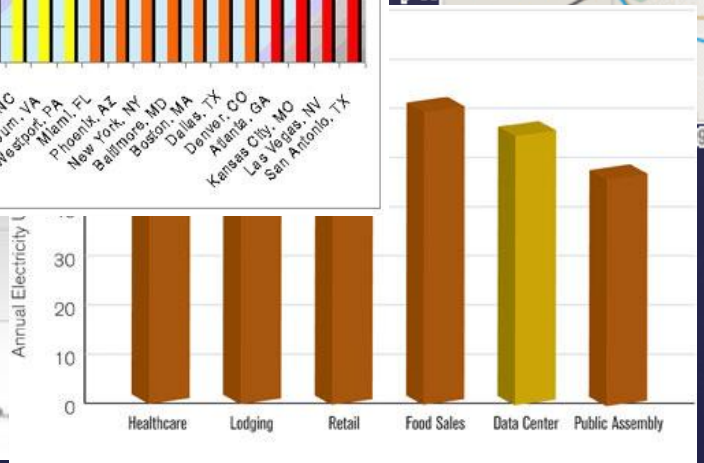
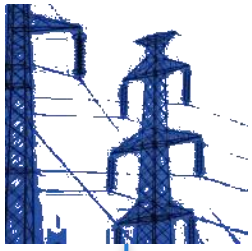

Annual Electricity
Healthcare
Lodging
Retail
Food Sales
Data Center
Public Assembly

Electrical & Mechanical Systems



gasoline

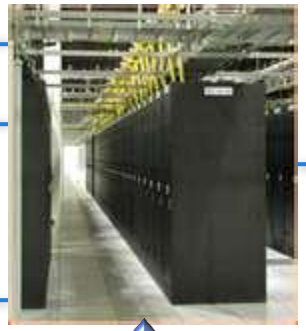
Generators

Power grid

Transformer

UPS

PDU



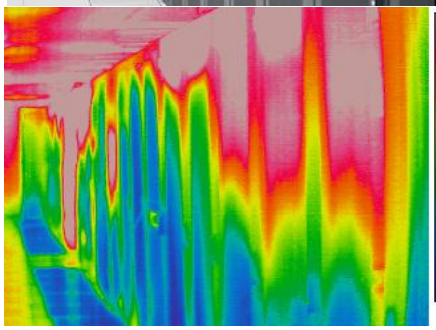
Racks

CRAC

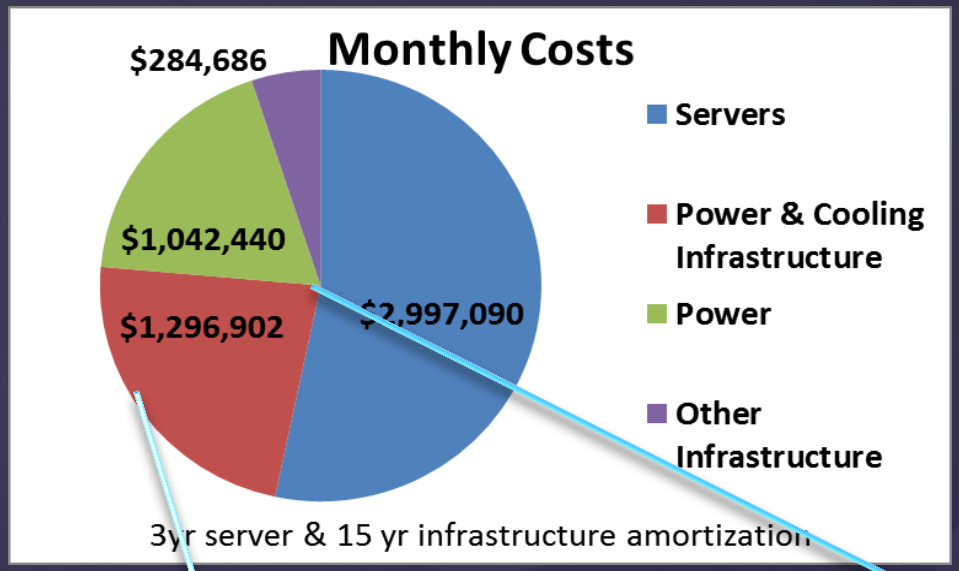
air

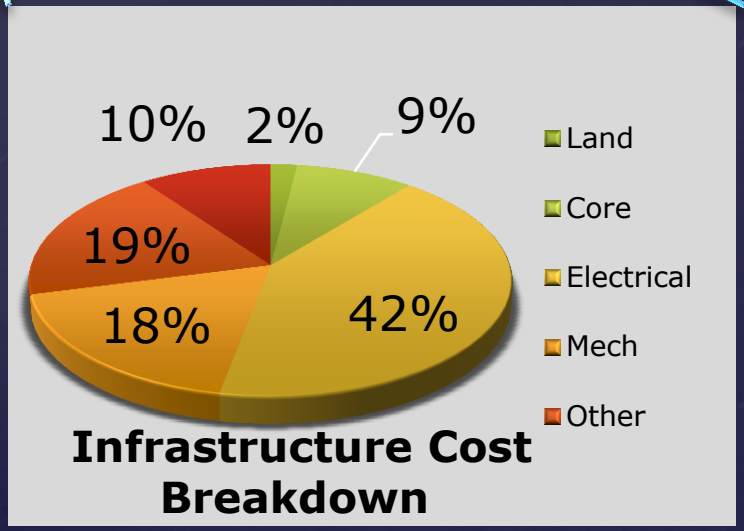
water

Water chillers



Infrastructure vs Tenants

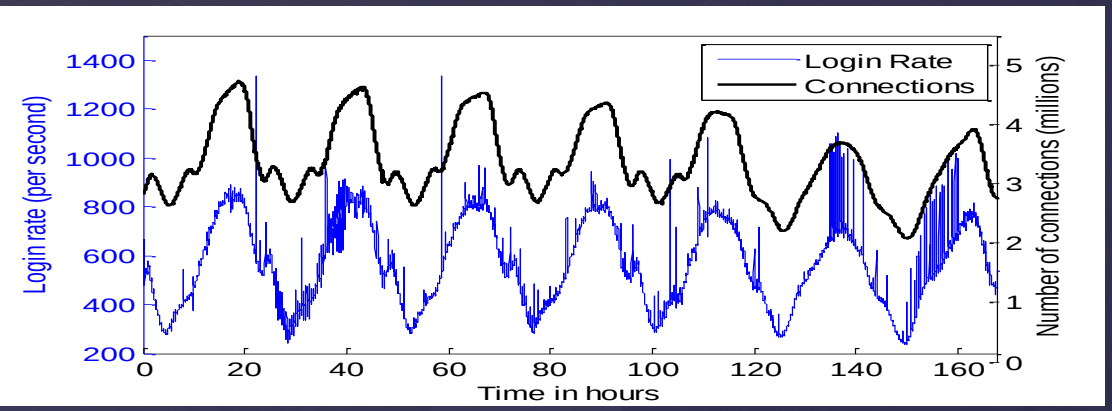




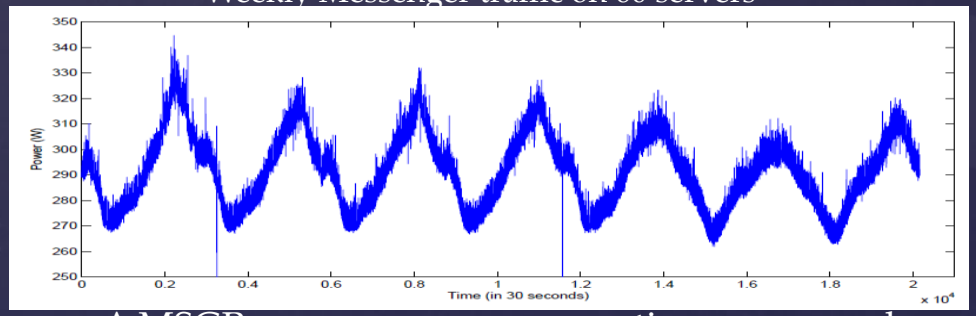
- A data center can host thousands to hundreds of thousands of servers and IT equipments.
- Data centers cost 100's of Millions to build. Most cost goes to electrical and mechanical systems.
- A single data center can consume over a hundred megawatt. Roughly 30%~50% of it goes to power and cooling systems
- Data center facilities have life time of 10 – 20 years. Once built, the infrastructure is hard to change
- Server models change every 2~4 years.

Figures courtesy: Hamilton and Manos

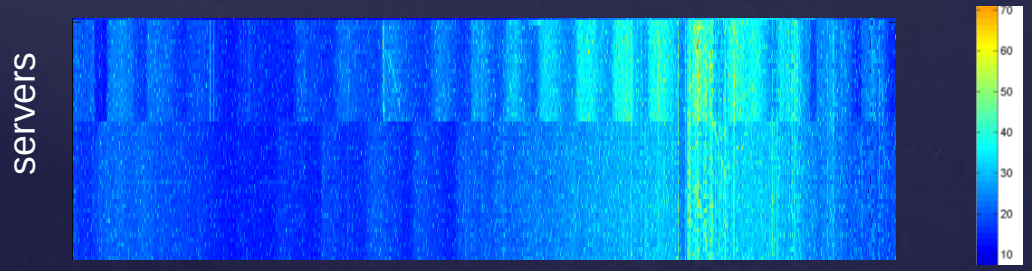
Computer Power Consumption



Weekly Messenger traffic on 60 servers

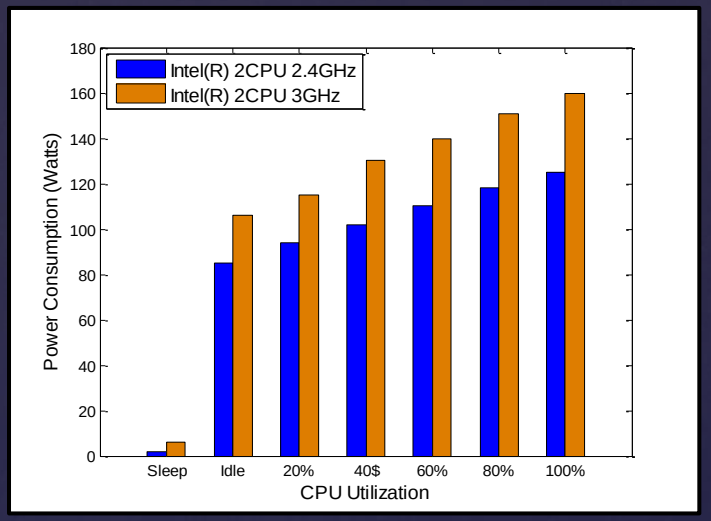


A MSGR server power consumption over a week



(CPU % of 50 MSGR servers over a day.)

Typical Server Power Consumption

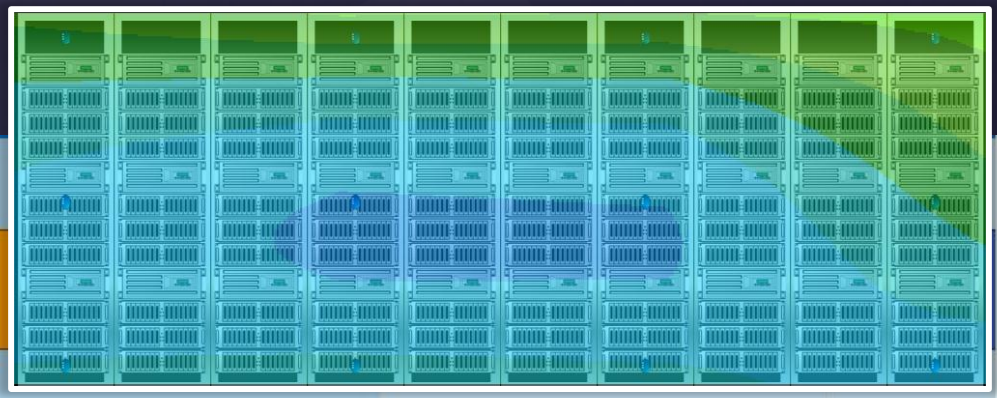


- Computing systems are getting elastic, with the help from virtualization and load dispatching.
- Many services are running globally spanning multiple data centers
- However, data centers need to be provisioned to handle peak load.

- Take advantage of renewable energy whenever it can.
- Pack uncorrelated servers (VMs) on the same power distribution line to reduce synchronized spikes.
- Distribute workload based on local cooling capacity to avoid creating hot spots
- Skew workload and shutdown unused servers.

Energy Proportional DCs

- Fine grained monitoring
- Modeling and prediction
- Joint optimization of physical and computing systems



Not that different from a smart building…

a smart sewage system…

or smart houses.

By bringing computing into the physical world, CPS promises to commoditize *intelligence.*

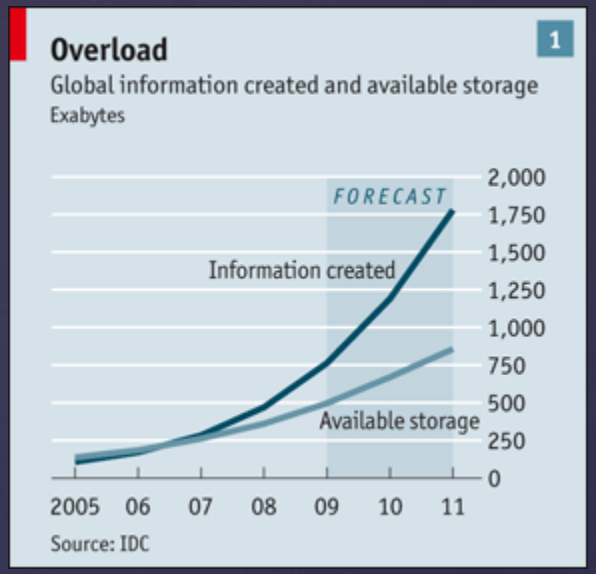


Figure from The Economists

- Taming system complexity
- Sensing and understanding the world
- Managing exabytes of data
- Large scale coordination and control

- Influencing user behavior
- Cyber-physical-behavior codesign
- Business models
- …

Plenty of Challenges Ahead.

Younger generations will be surprised that we have ever had to …