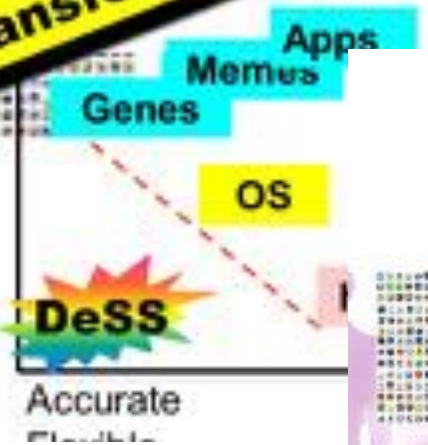
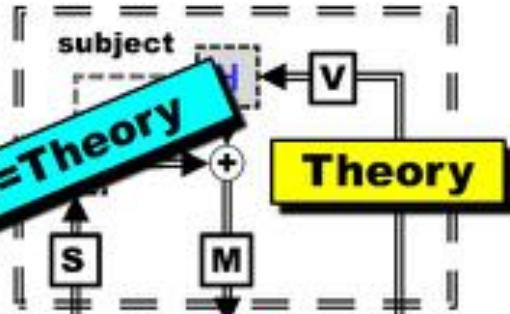
Architectures: Good, Bad, Ugly, Hijacked,...

Generative
Modular
Compos

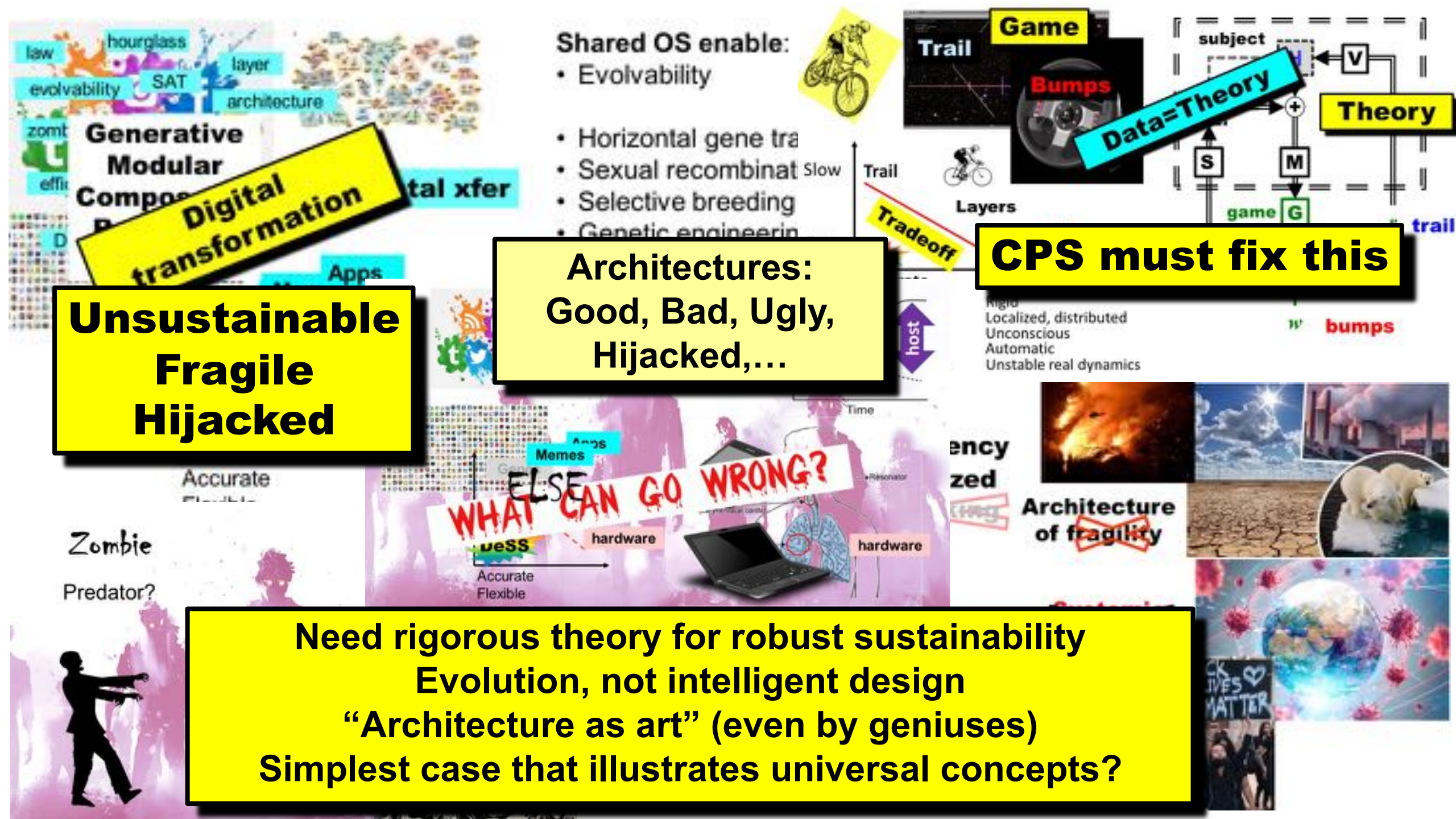
Digital transformation



Shared OS enable:
- Evolvability
- Horizontal gene tra
- Sexual recombinat



ency
zed


law
hourglass
layer
evolvability
SAT
architecture
Generative
Modular
Digital transformation
Shared OS enable:
• Evolvability
• Horizontal gene tra
• Sexual recombinat
• Selective breeding
Slow
Trail
Tradeoff
Layers
Trail
Game
Bumps
Data=Theory
subject
V
Theory
S
M
game
G
trail
CPS must fix this
Unsustainable
Fragile
Hijacked
Architectures:
Good, Bad, Ugly,
Hijacked,…
Apps
host
Localized, distributed
Unconscious
Automatic
Unstable real dynamics
bumps
Accurate
Memes
ELSE
WHAT CAN GO WRONG?
hardware
hardware
Time
Accurate
Flexible
Architecture
of fragility
Zombie
Predator?
Need rigorous theory for robust sustainability
Evolution, not intelligent design
“Architecture as art” (even by geniuses)
Simplest case that illustrates universal concepts?

Current architecture priorities (JCD):

- Theory: SLS (SysLevelSyn), LAO (LayerAsOpt), Learning and control, Cyber *and* physical
- Cancer immunology (development, wounds, infections)
- Neuro, sensorimotor, language, mental illness
- Microbiomes, biofilms
- Social, political, economic

Need rigorous theory for robust sustainability

~~**Evolution, not intelligent design**~~

~~**"Architecture as art" (even by geniuses)**~~

Simplest case that illustrates universal concepts?

Current architecture priorities:

- Theory: SLS (SysLevelSyn), LAO (LayerAsOpt), Learning and control, Cyber *and* physical
- Cancer immunology (development, wounds, infections)
- **Neuro, sensorimotor**, language, mental illness
- Microbiomes, biofilms
- Social, political, economic (most intractable, most essential)
- Consciousness, feelings, free will (most confused)

Need rigorous theory for robust sustainability

Evolution, not intelligent design

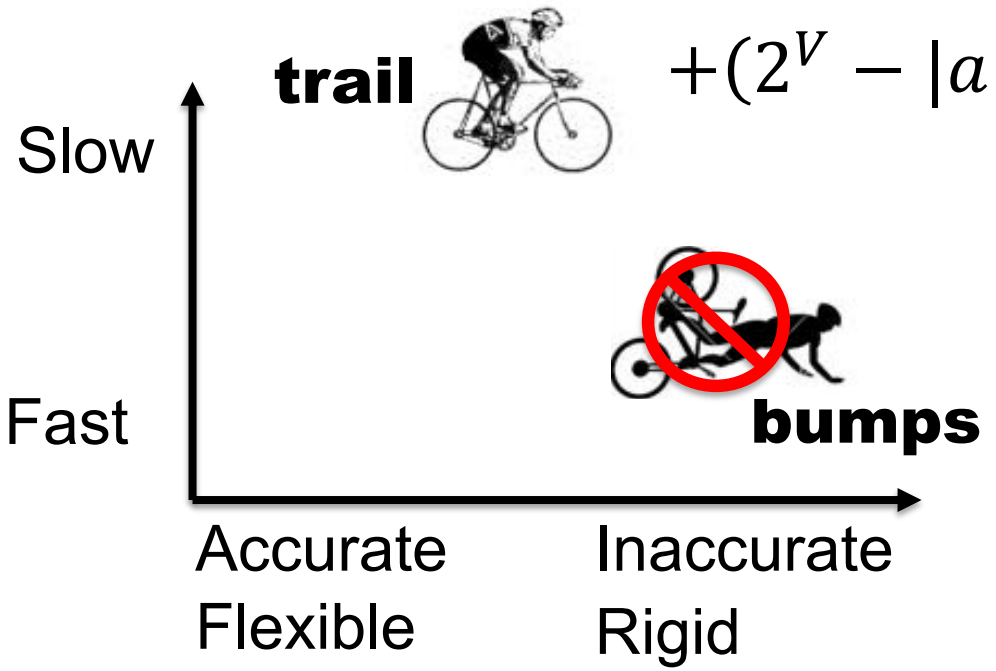
"Architecture as art" (even by geniuses)

Simplest case that illustrates universal concepts?

Diversity-enabled sweet spots in layered architectures and speed-accuracy trade-offs in sensorimotor control

Yorie Nakahira, Quanying Liu, Terrence J. Sejnowski, and John C. Doyle

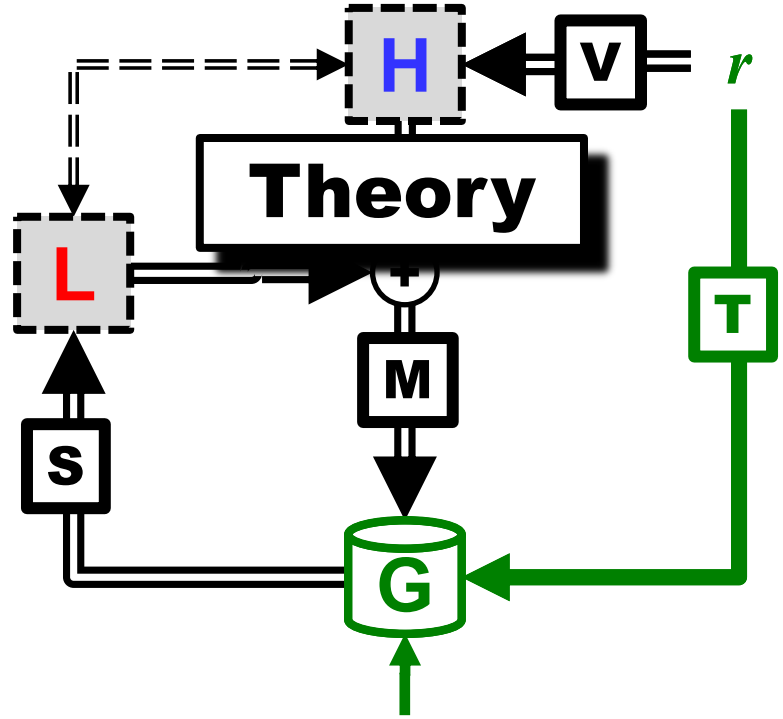
PNAS 2021



$$+(2^V - |a|)^{-1}$$

Layers

$$\delta\left(\sum_{i=1}^{T}|a^{i-1}| + |a^T|\left(2^{\lambda T} - |a|\right)^{-1}\right)$$



Simplest case that illustrates universal concepts?

Laws, layers, levels, diversity, sweet spots, SLS

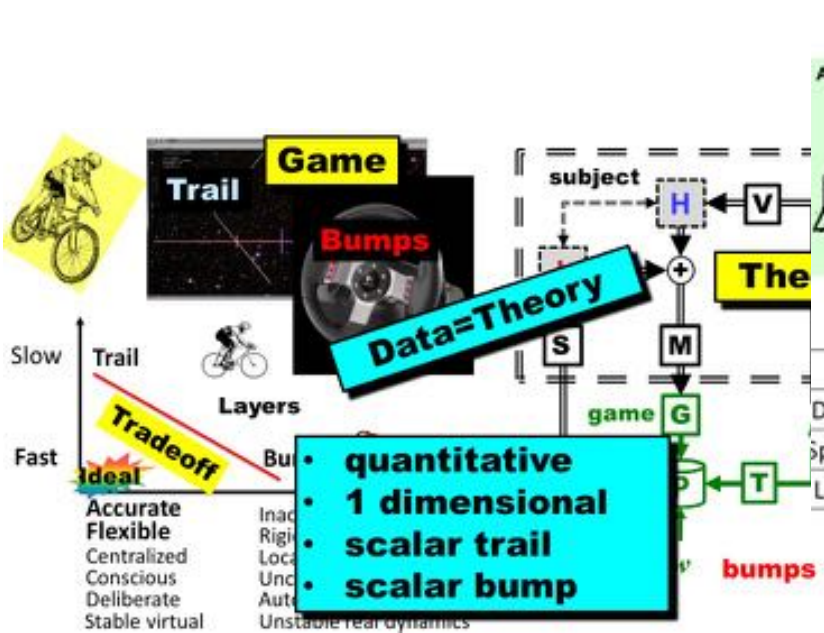
Cells
Organisms
Immune Sys
Brains
Language
Societies
Ecosystems

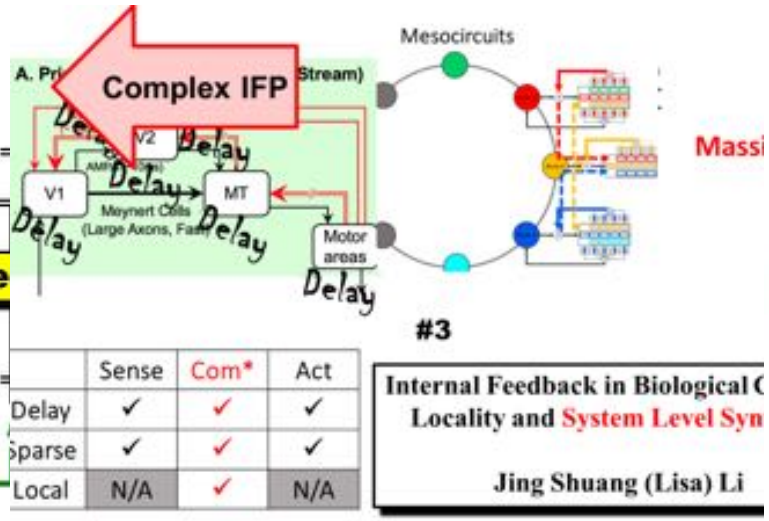
Phones
Computers
Internet
Power
Utilities
Vehicles
Transport

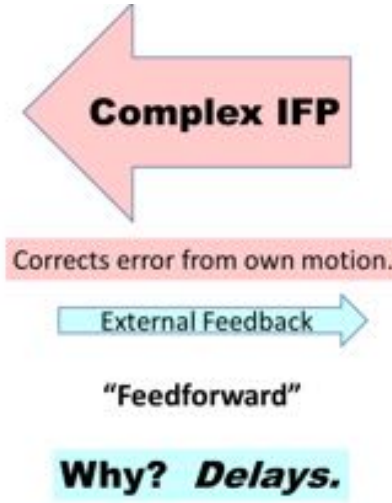
Supply Chains
Buildings
Cities
Countries
Finance
Laws
Judicial system

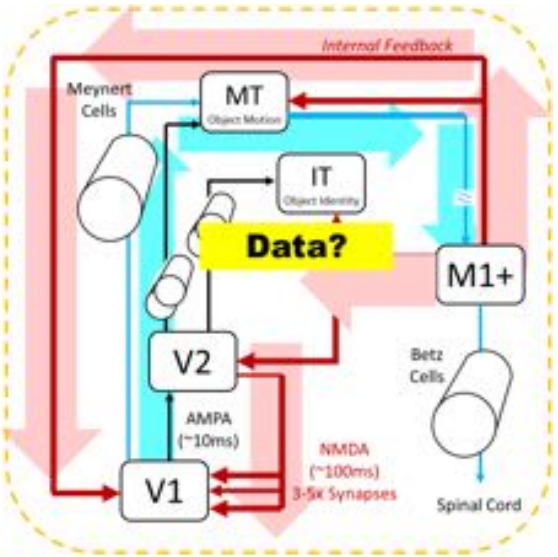
Clothing
Cooking
Baking
Legos

Function, protocols, virtual, flexible, evolve, adapt, fragile, hidden, hijacked





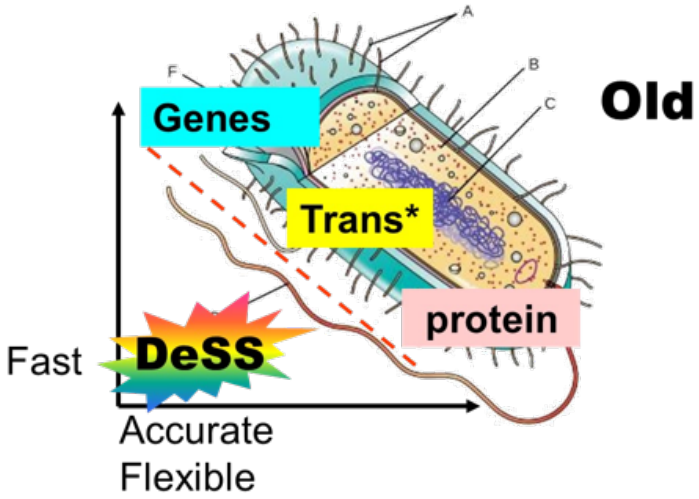




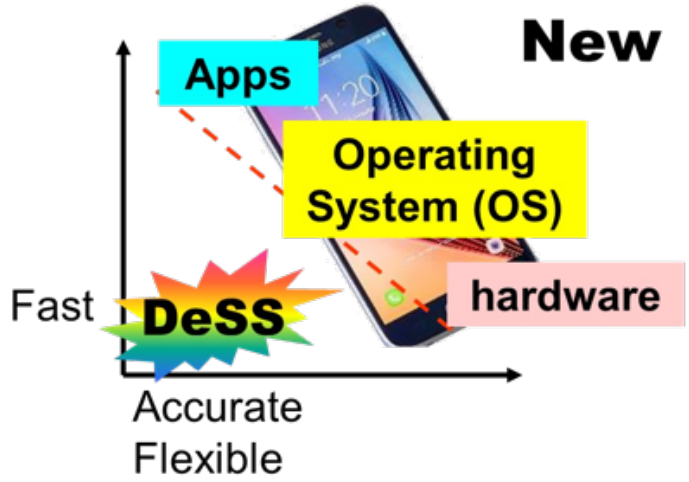
Laws, layers, levels, diversity, sweet spots

Cells	**Cell (Phones)**	Supply Chains	Clothing
Organisms	Computers	Buildings	Cooking
Immune Sys	Internet	Cities	Baking
Brains	Power	Countries	Legos
Language	Utilities	Finance	
Societies	Vehicles	Laws	
Ecosystems	Transport	Judicial system	

Function, protocols, virtual, flexible, evolve, adapt, fragile, hidden, hijacked



Layered architectures

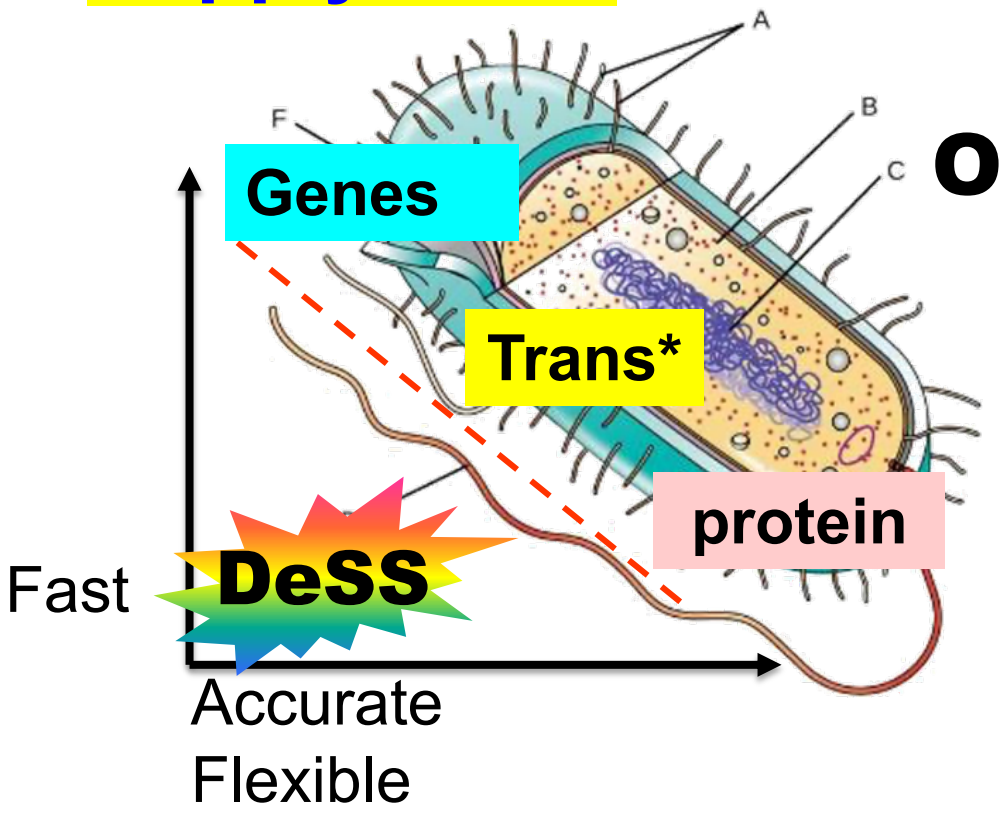


Remarkably shared ParArch

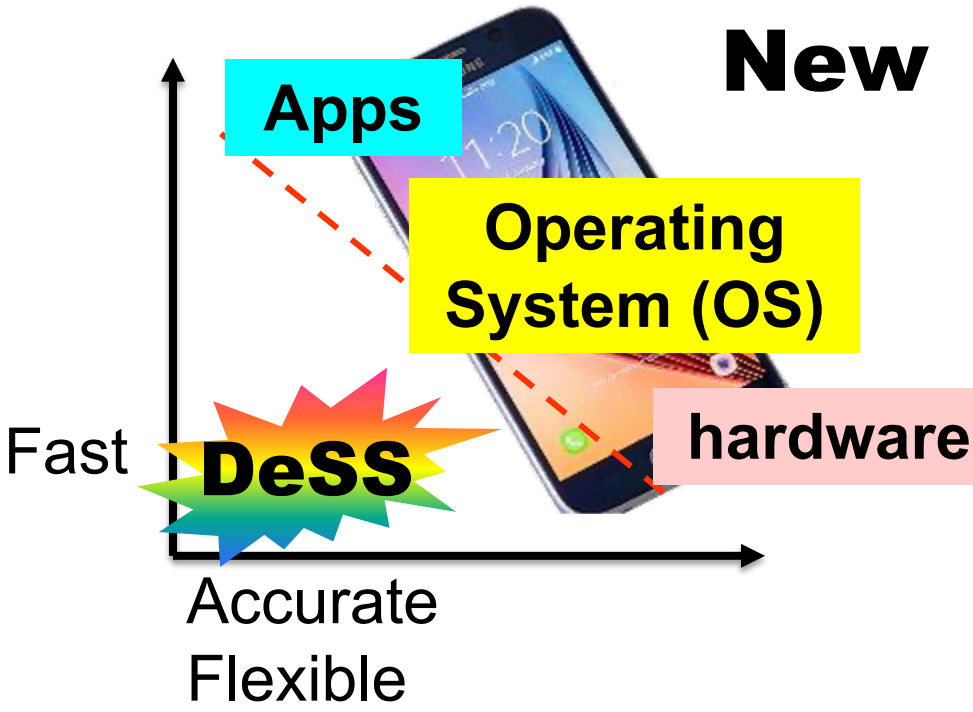
Genes
Networked
Swappable
Diverse
Supply chain

Good examples?

Apps
Networked
Swappable
Diverse



Diversity Enabled Sweet Spot



All (parallel) architectures: Laws, layers, levels, diversity, sweet spots

Cells
Organisms
Immune Sys
Brains
Medical physiology
Societies
Ecosystems

Cell (Phones)
Computers
Internet
Power
Utilities
Vehicles
Transport

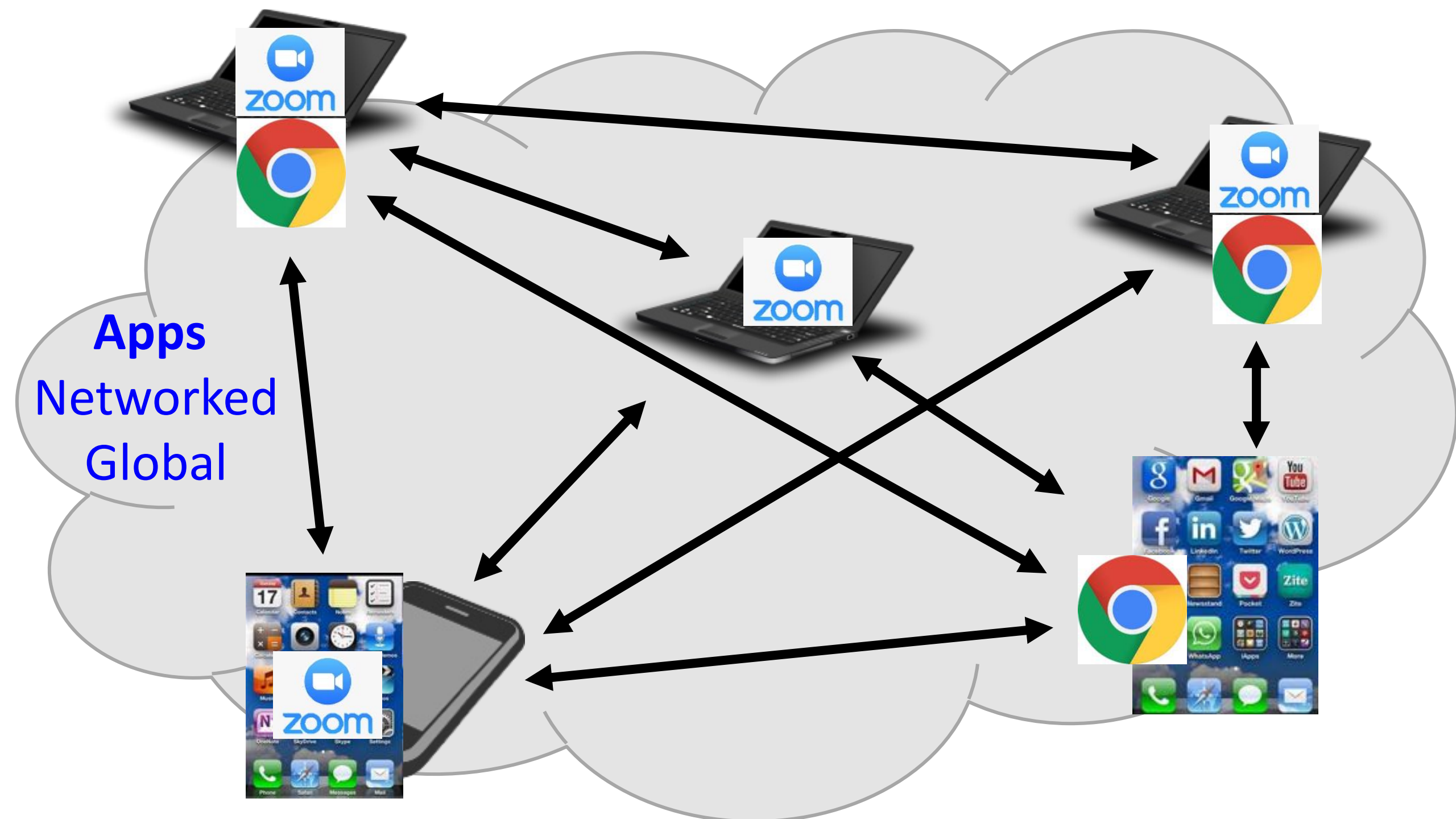
Supply Chains
Buildings
Cities
Countries
Finance
Laws
Language

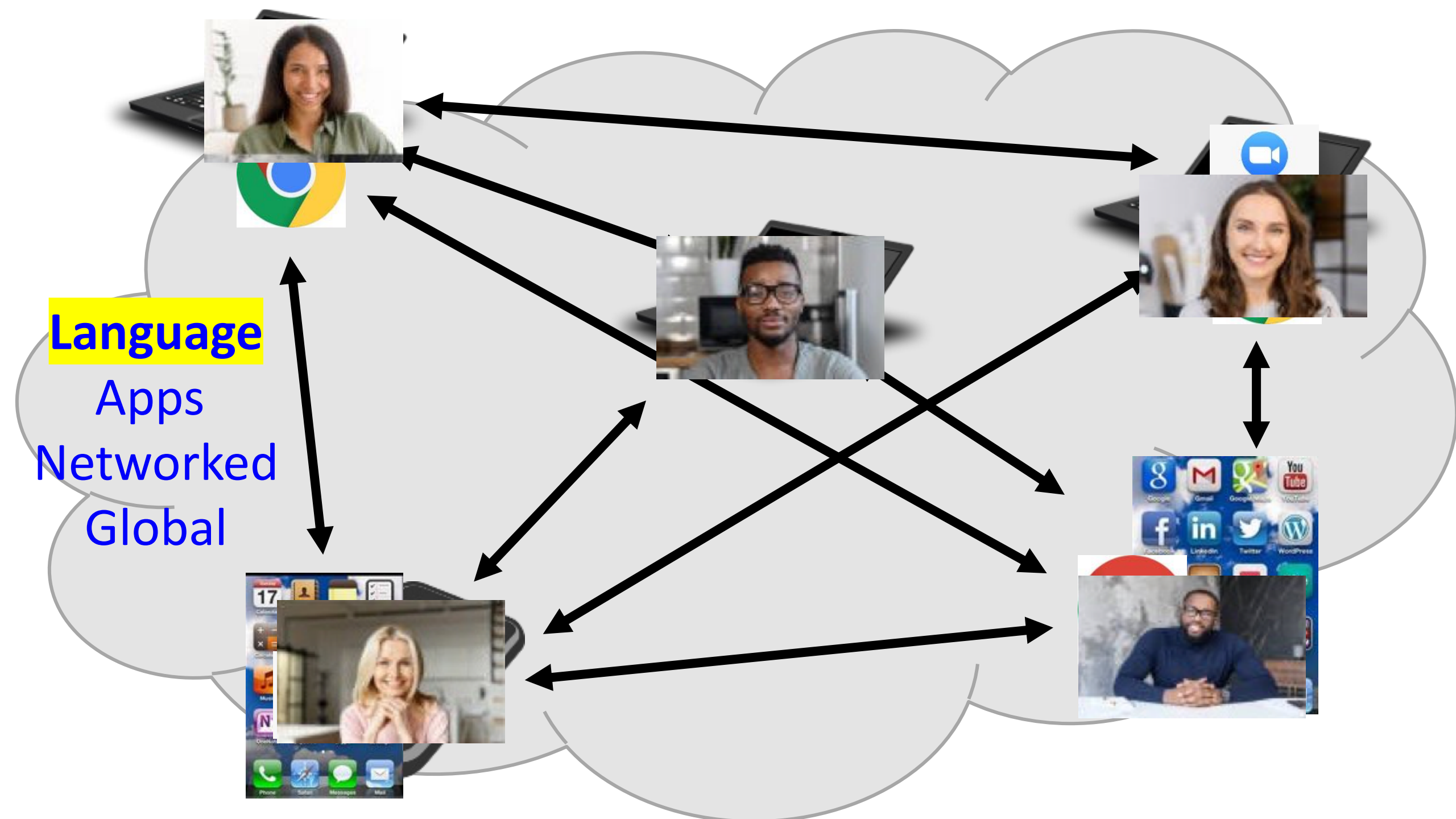
Clothing
Cooking
Baking
Legos

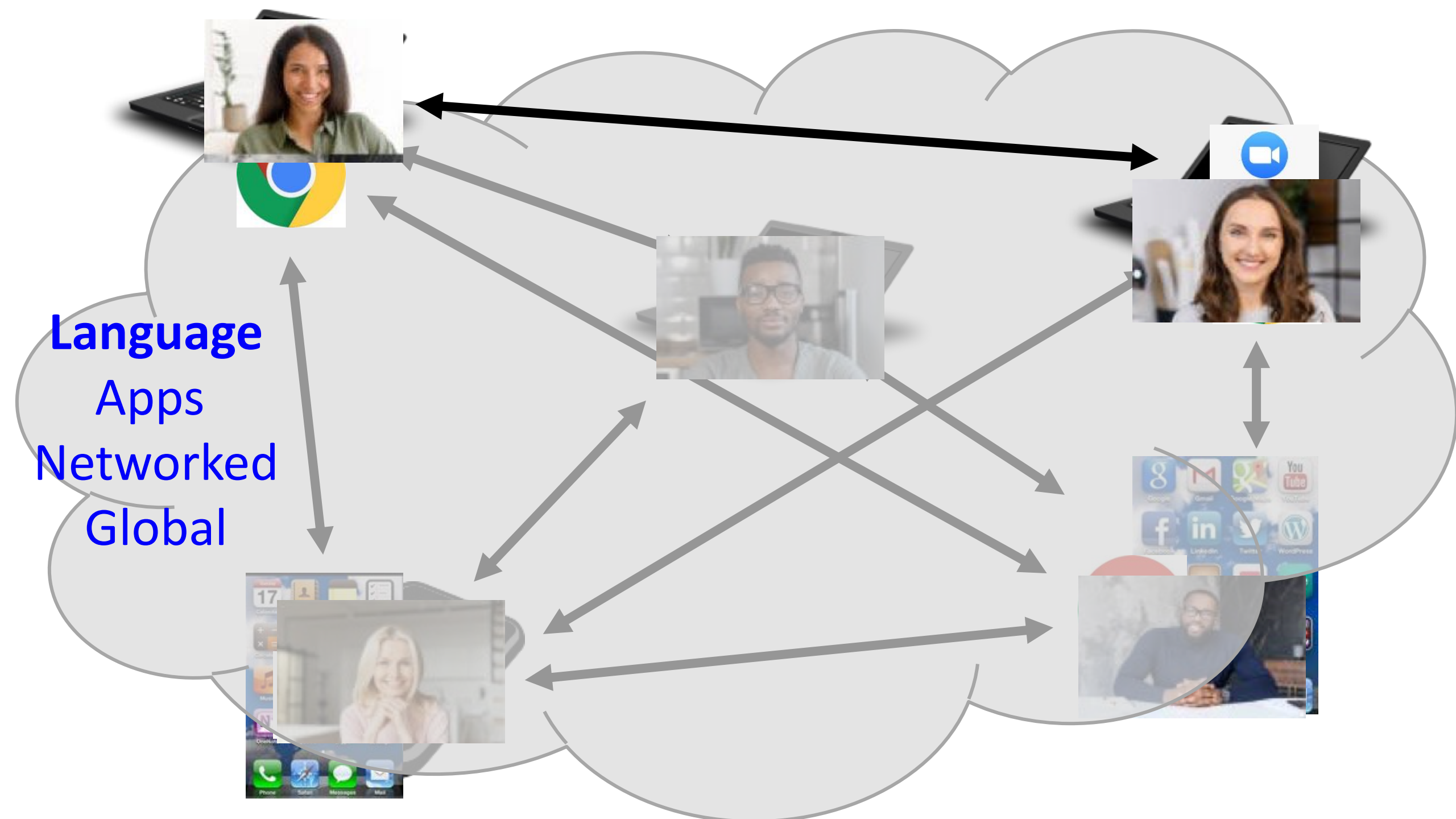
High impact science (noncontrol) publications:
Science, Cell, PNAS, PRL, …

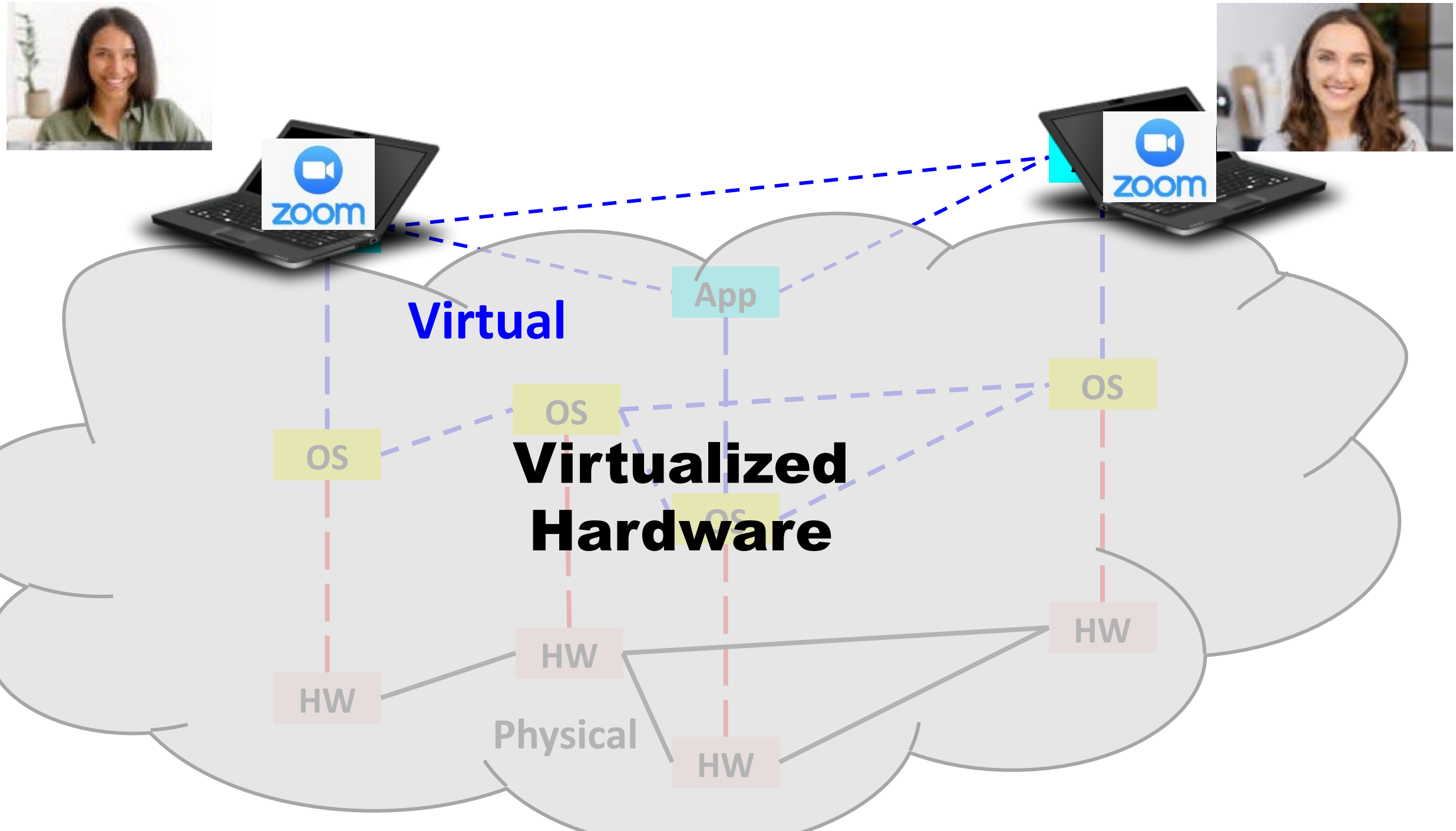
- **Big impact in engineering**
- **Minimal acceptance in science**

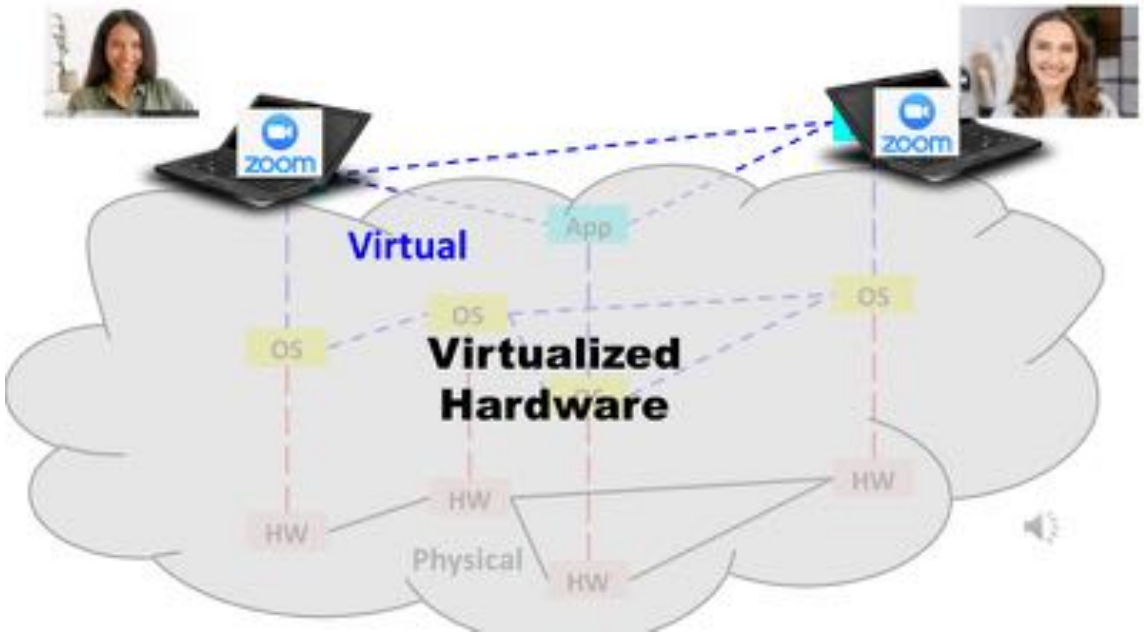
- Eager to discuss in any level of detail
- Subject of this year's courses in CDS@Caltech

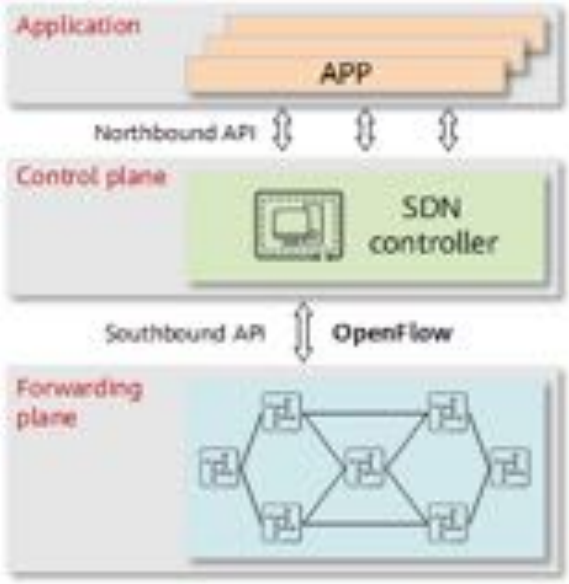

Apps
Networked
Global
zoom
zoom
zoom
zoom

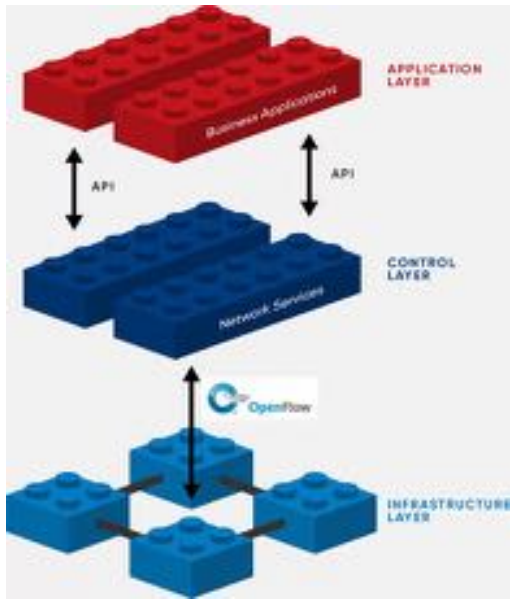

Language
Apps
Networked
Global

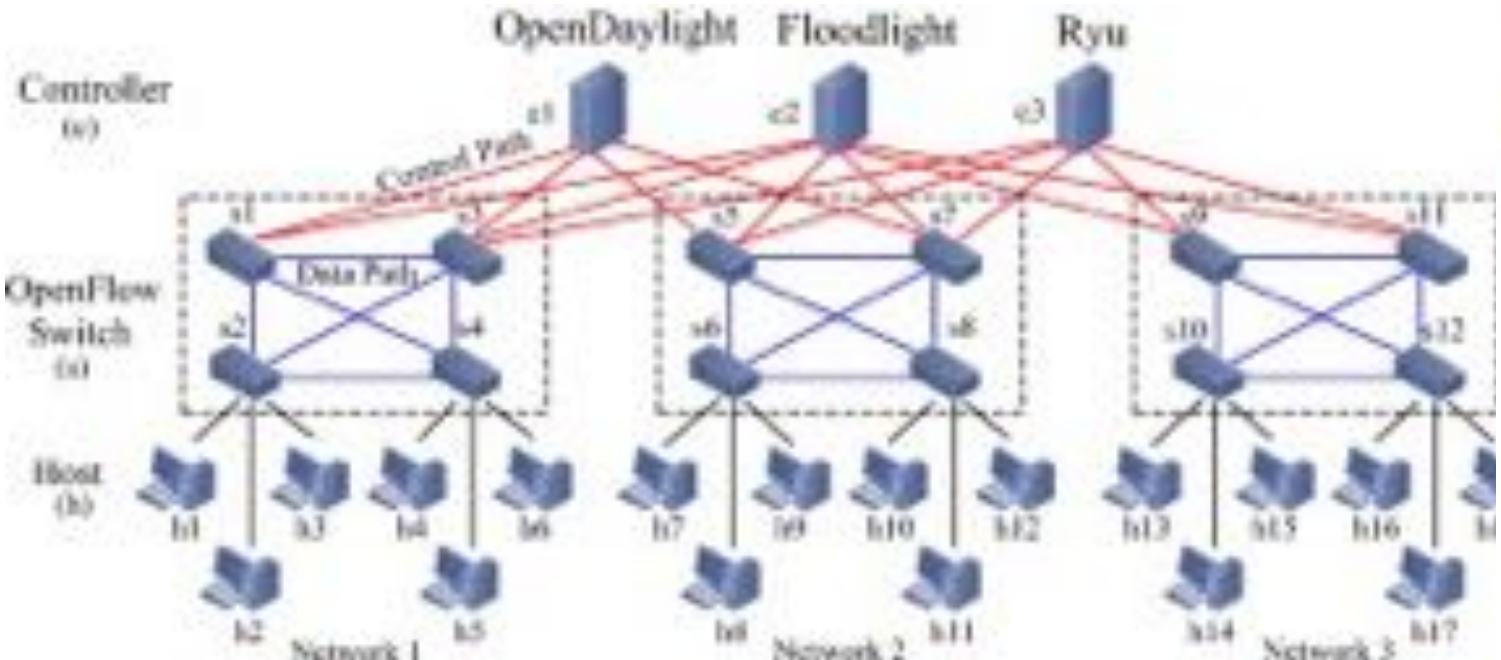

Language
Apps
Networked
Global


zoom
zoom
Virtual
App
OS
OS
OS
Virtualized
Hardware
HW
HW
HW
Physical
HW









Evolve or Die: High-Availability Design Principles Drawn from Google's Network Infrastructure

Ramesh Govindan[†⋆], Ina Minei[†], Mahesh Kallahalla[†], Bikash Koley[†], Amin Vahdat[†]
[†]Google [⋆]University of Southern California

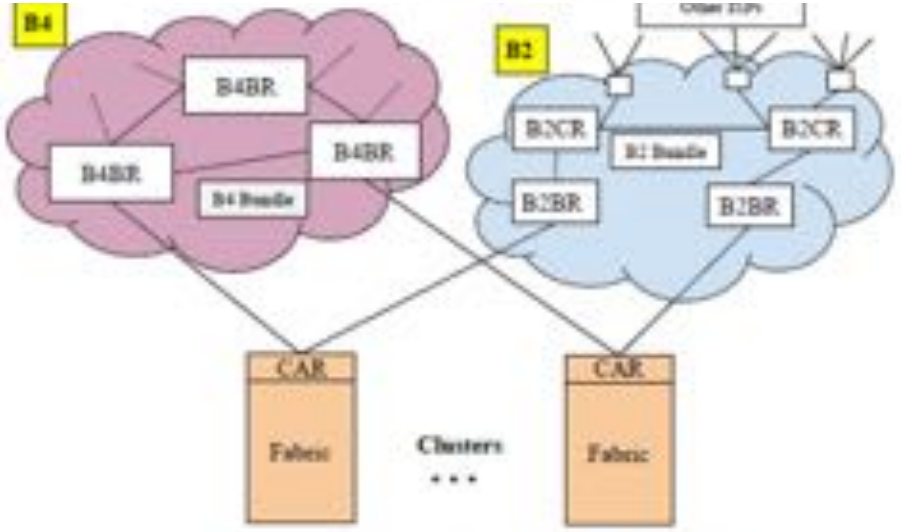


Figure 1: Google's Global Network

Language
Apps
Global
Diverse

Virtual

Layered

App

OS

OS

OS

OS

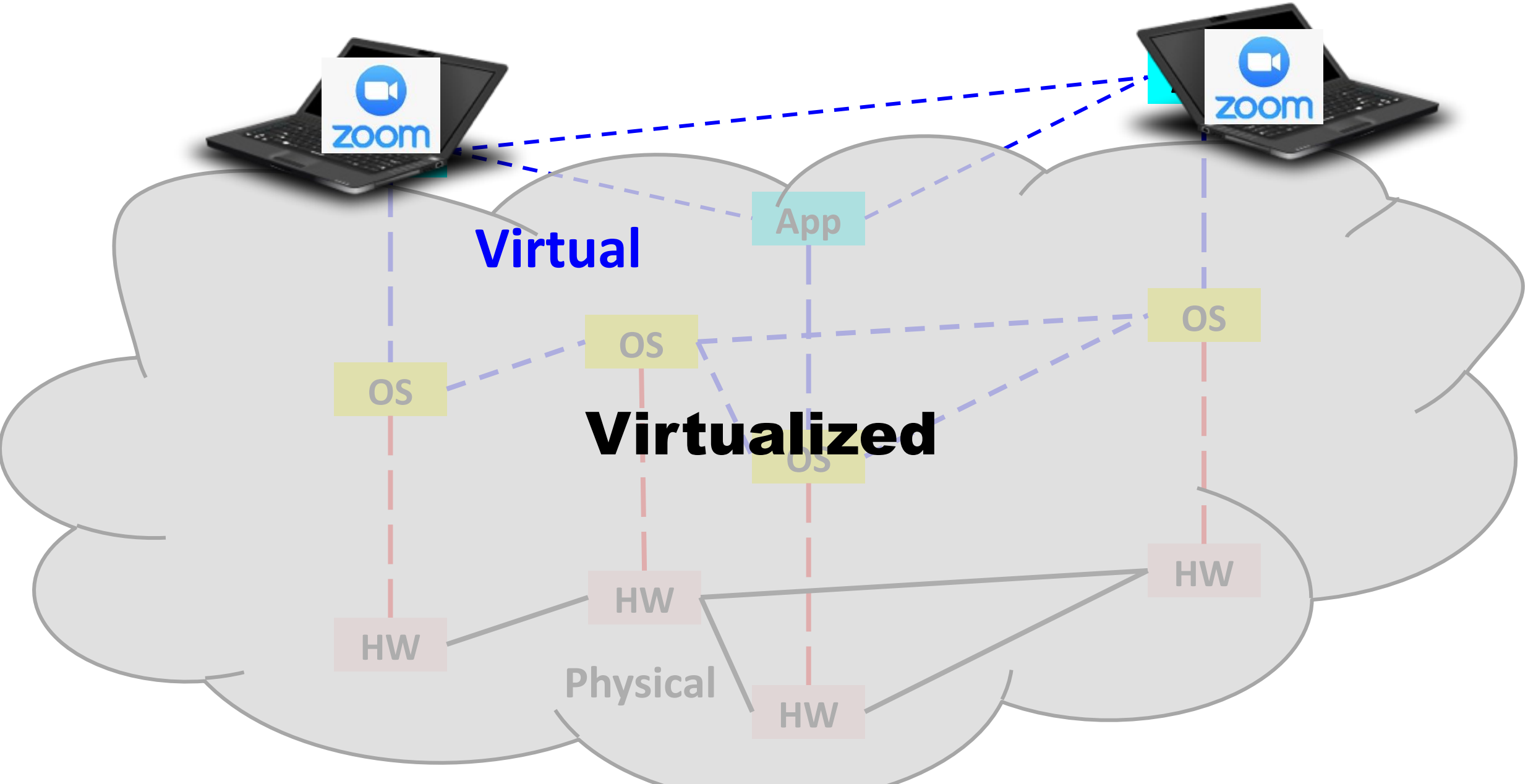
HW

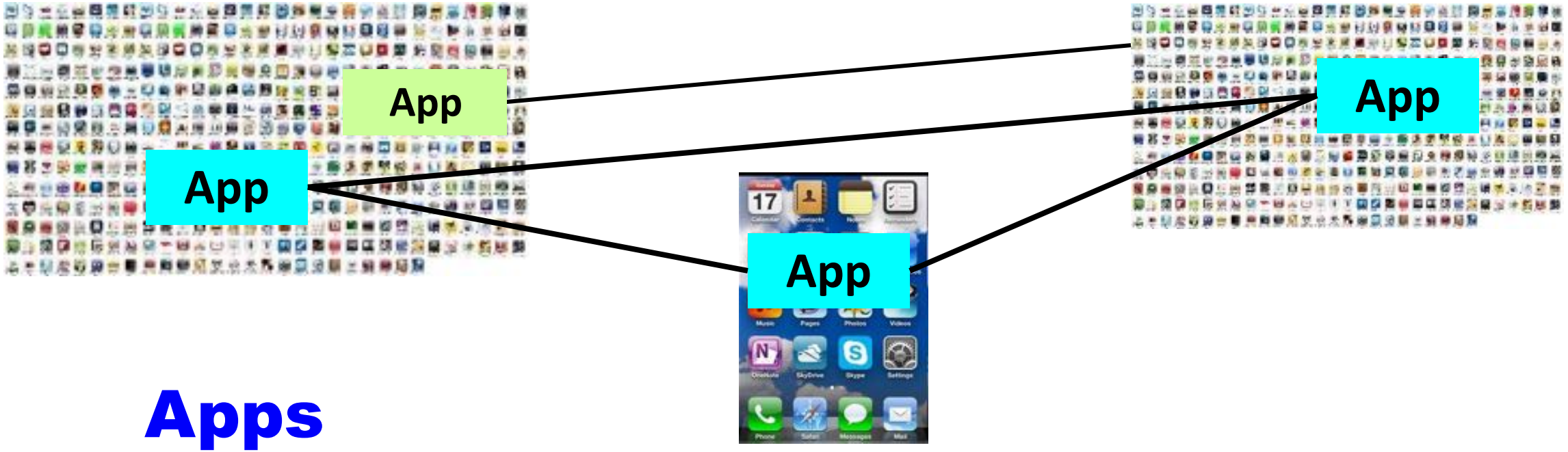
HW

HW

HW

Physical
Local
Less diverse


zoom
zoom
Virtual
App
OS
OS
OS
Virtualized
OS
HW
HW
HW
Physical
HW



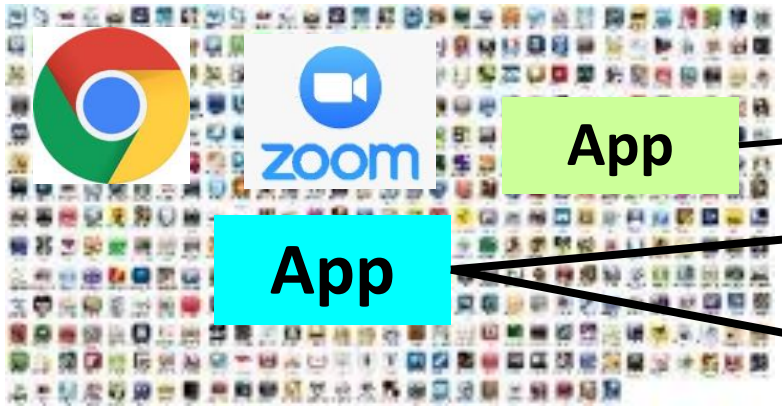
Apps

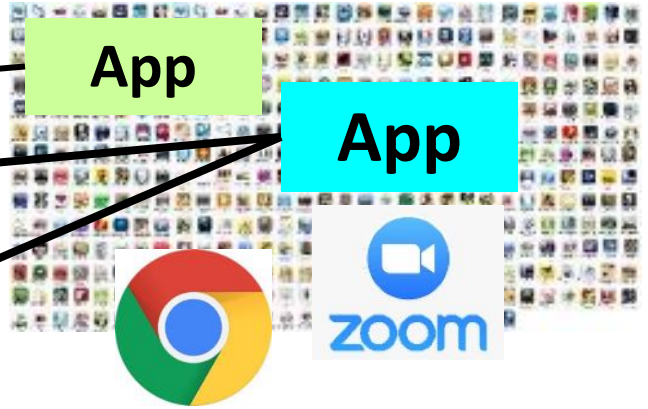
Networked

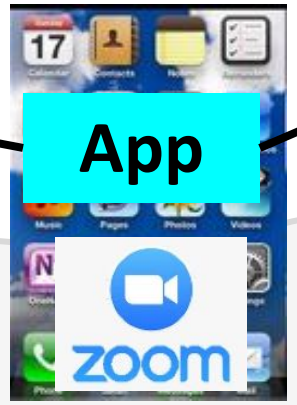
Swappable

Diverse

Parallel architecture







Apps

Networked

Swappable

Diverse

Virtual?

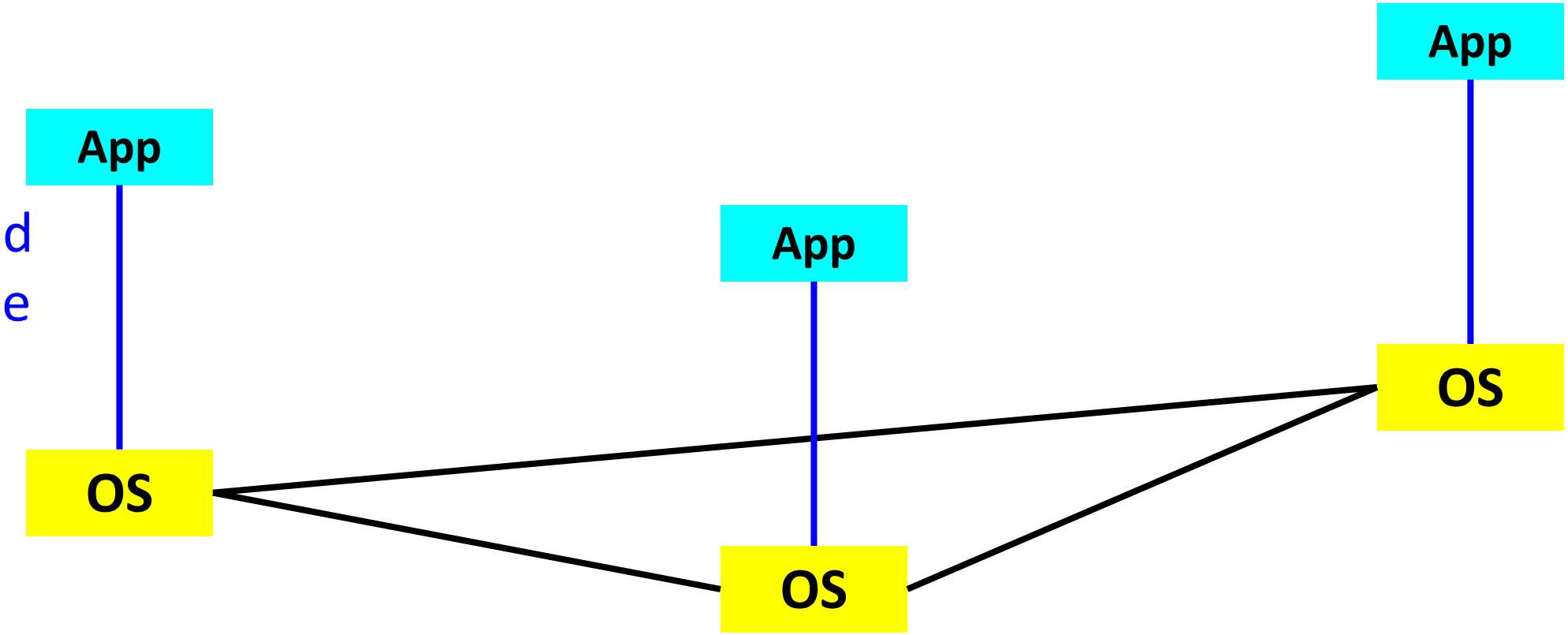
Parallel architecture

Apps

Networked

Swappable

Diverse



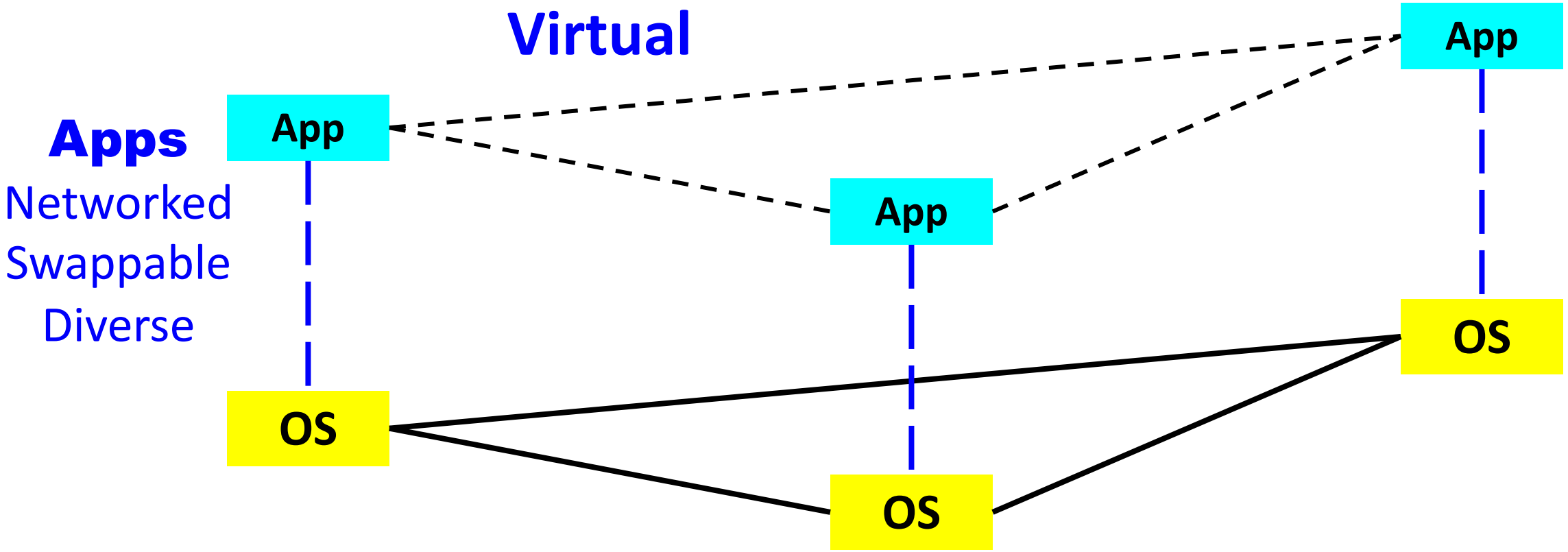
Operating System (OS)

OS (software)

Networked

~~**Swappable**~~

~~**Diverse**~~



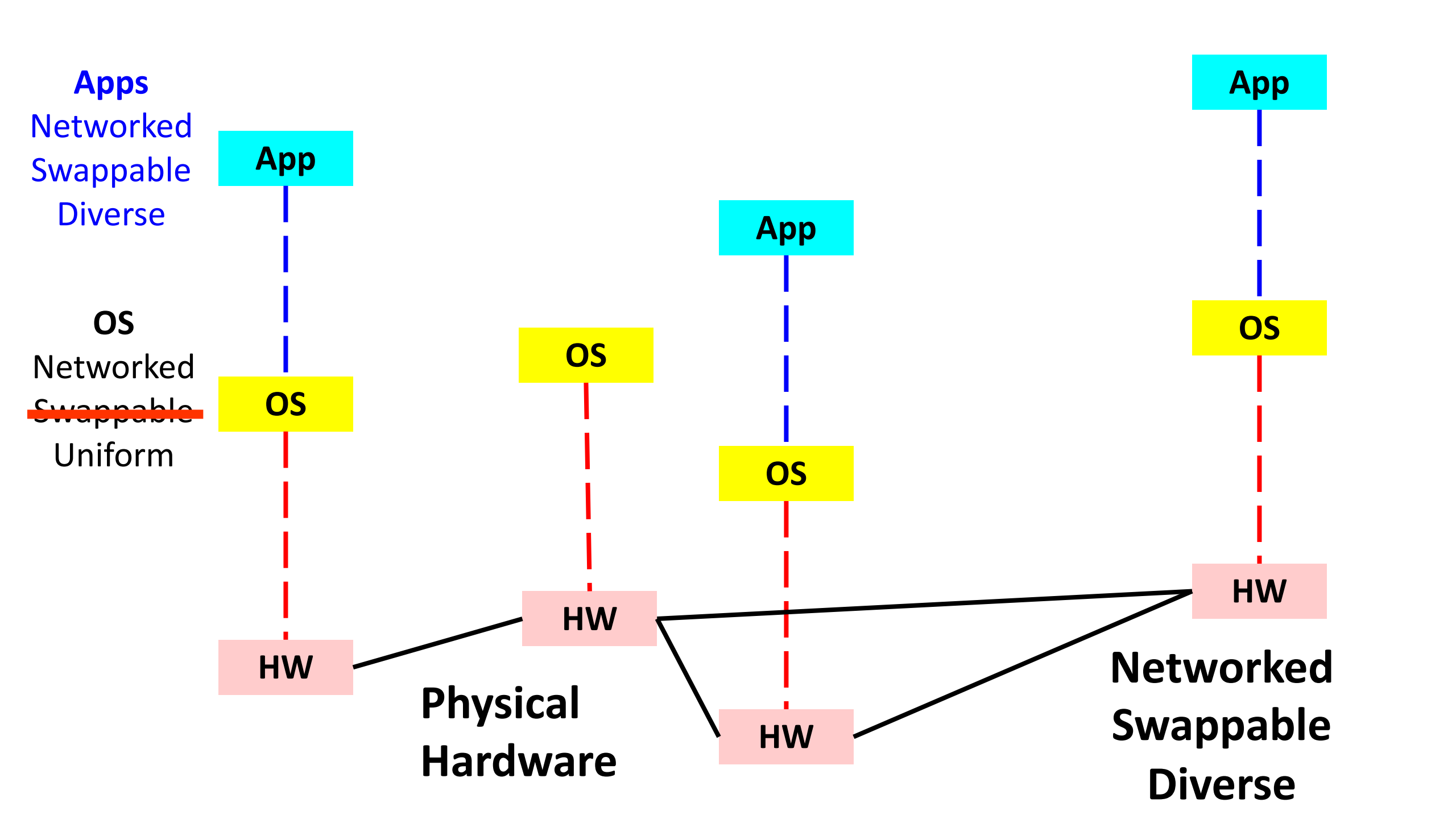
Operating System (OS)

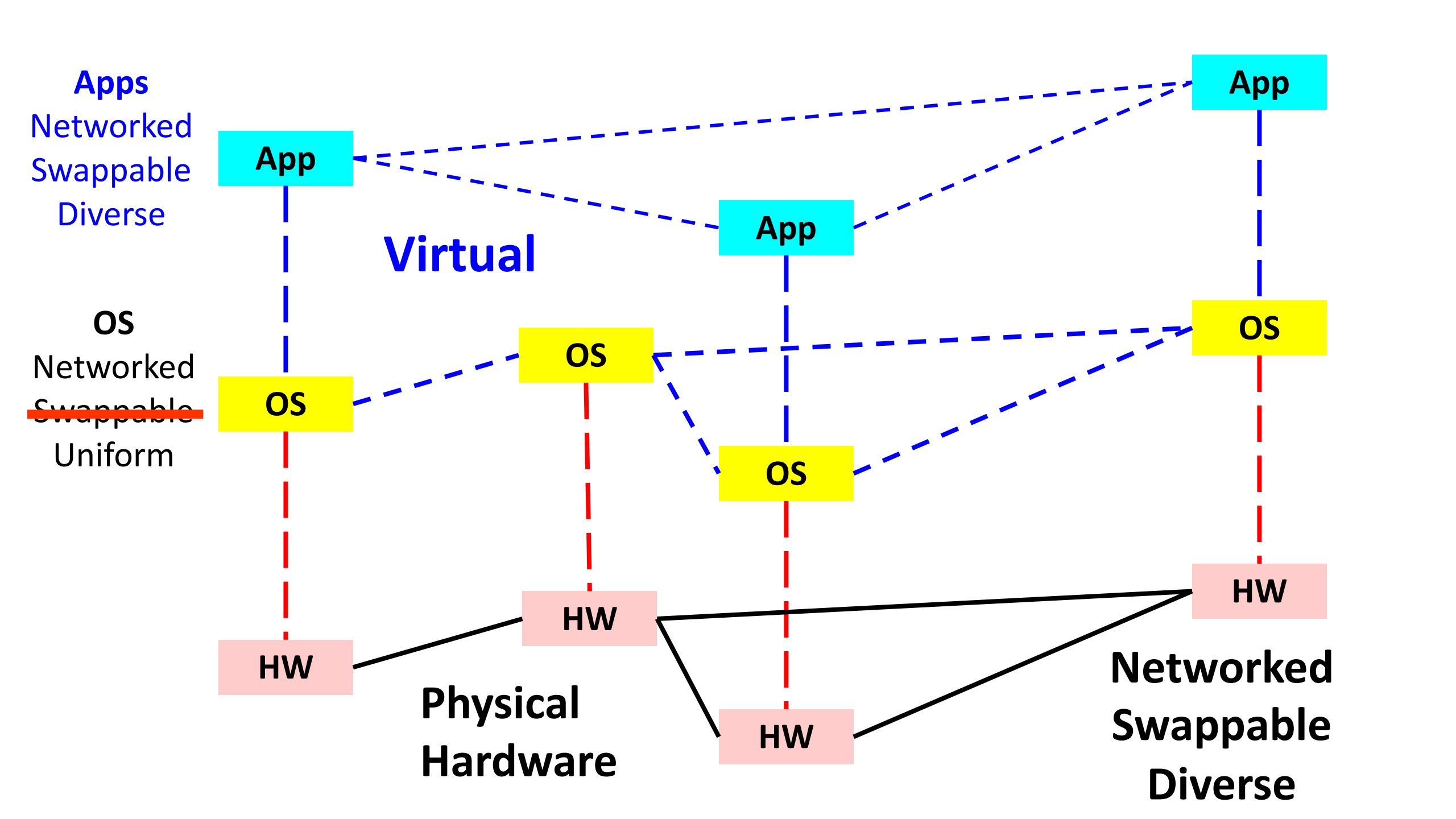
OS

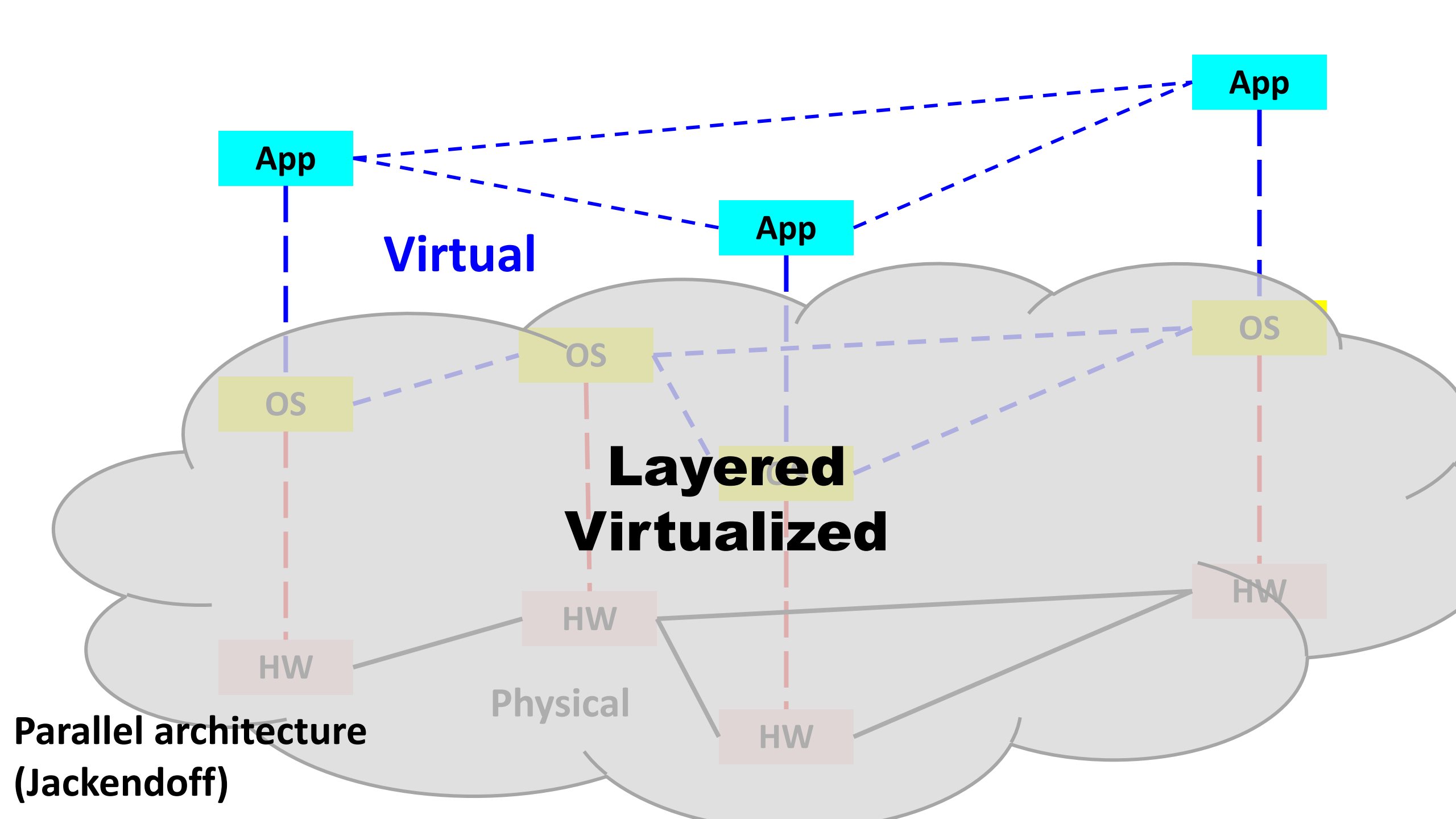
Networked

~~**Swappable**~~

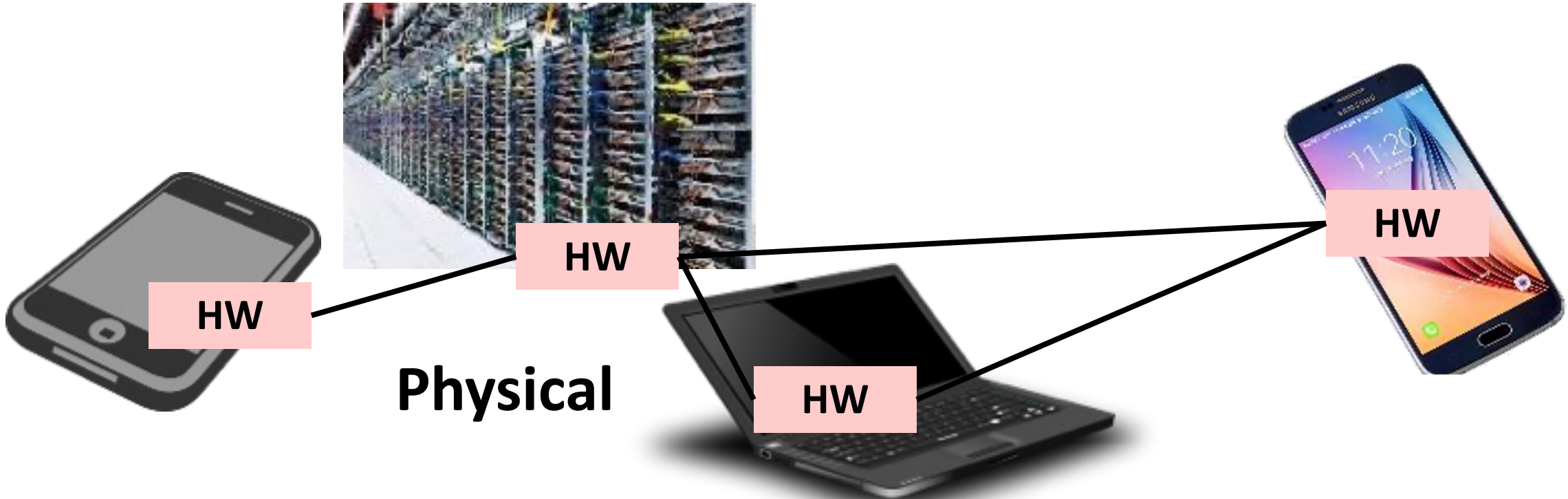
~~**Diverse**~~

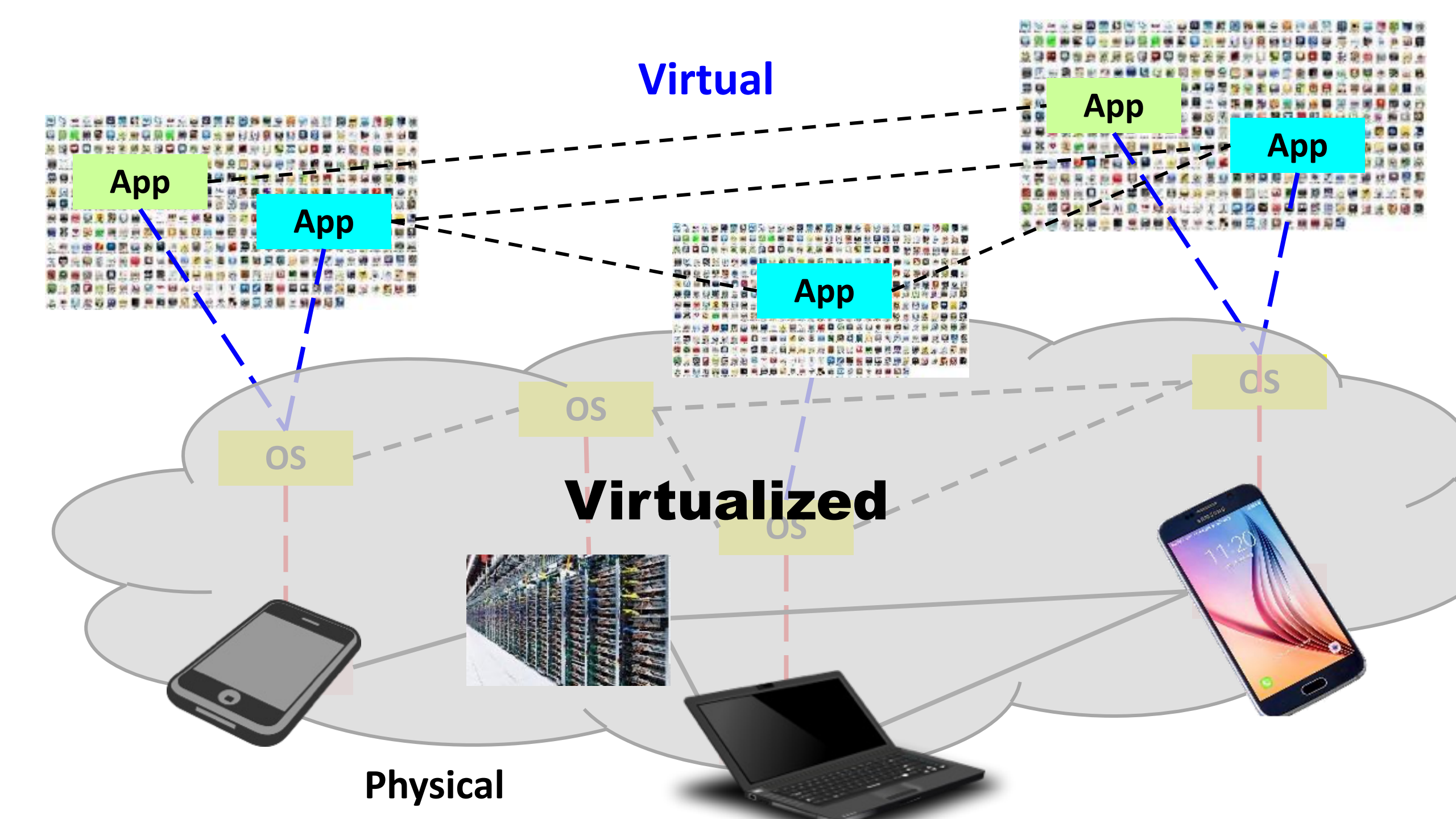

Apps
Networked
Swappable
Diverse
OS
Networked
~~Swappable~~
Uniform
App
OS
HW
App
OS
HW
App
OS
HW
Physical
Hardware
Networked
Swappable
Diverse

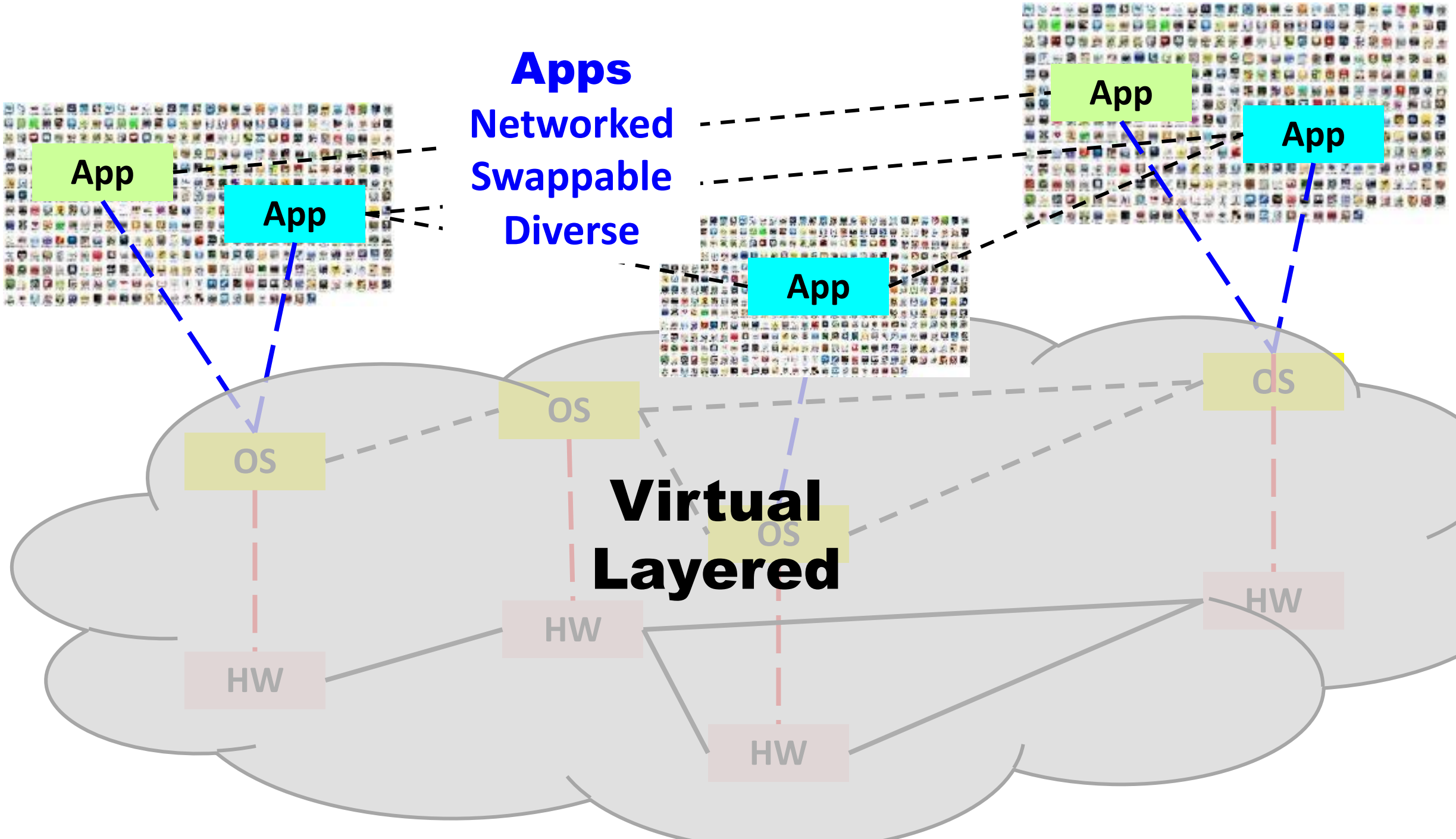

Apps
Networked
Swappable
Diverse
OS
Networked
~~Swappable~~
Uniform
App
App
App
Virtual
OS
OS
OS
OS
HW
HW
HW
HW
Physical
Hardware
Networked
Swappable
Diverse



Parallel architecture (Jackendoff)


HW
HW
HW
HW
Physical

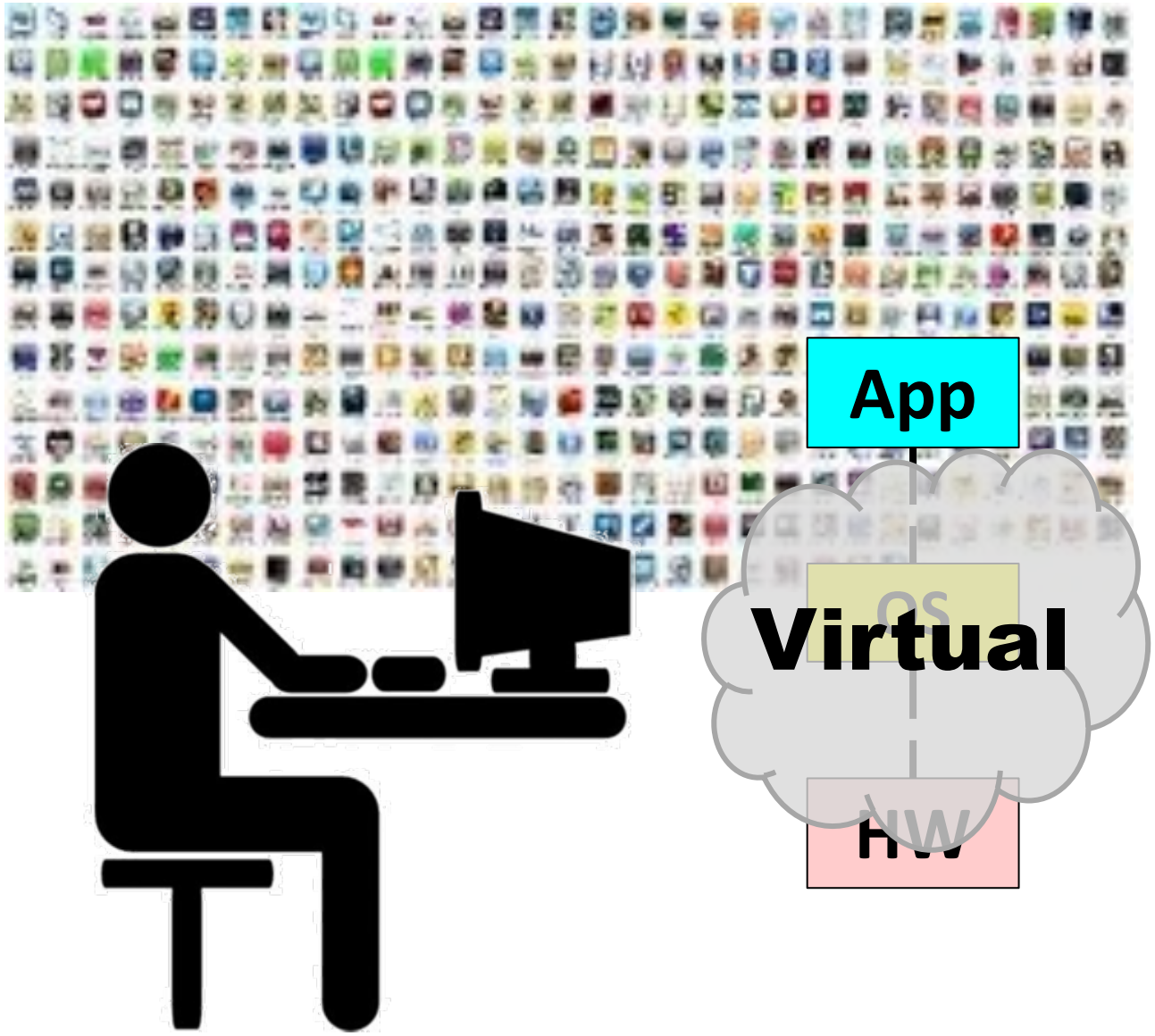

Virtual
App
App
App
App
App
OS
OS
OS
OS
Virtualized
Physical


Apps
Networked
Swappable
Diverse
App
App
App
App
App
OS
OS
OS
OS
HW
HW
HW
Virtual
Layered

Layered architecture

Virtual

Layered architecture



Virtual
“automatic”
“unconscious”

Layered architecture

App

OS

HW

Virtual

App

OS

HW

App

OS

HW

Virtual
"automatic"
"unconscious"

Hardware

Parallel ~~Layered~~ architecture

Diversity hourglass

Swappable
Diverse

Not

Diverse
Swappable