

Au-delà de la nouveauté !

*Défis sur la gestion de l'intelligence collective dans
une société connectée*

Beyond the hype !

Challenges on the leverage of
collective intelligence in a connected society

**Premières rencontres « Architecture & Intelligences »
École nationale supérieure d'architecture Paris Val de Seine**

Juan-Antonio Cordero-Fuertes, École Polytechnique
June 2019



Roadmap

- AI, from the imaginary to the real world
- Intelligence, learning and intelligent systems
- Intelligent connected systems : the importance of scale
- Implications
 - Data centrality
 - Aggregation and collective intelligence
 - Enabling technologies
- Further (social) considerations : looking ahead



AI in science fiction

WOPR
(WarGames, 1983)



Skynet
(Terminator, 1984)



The Matrix
(1999)

Black Mirror
(2011)

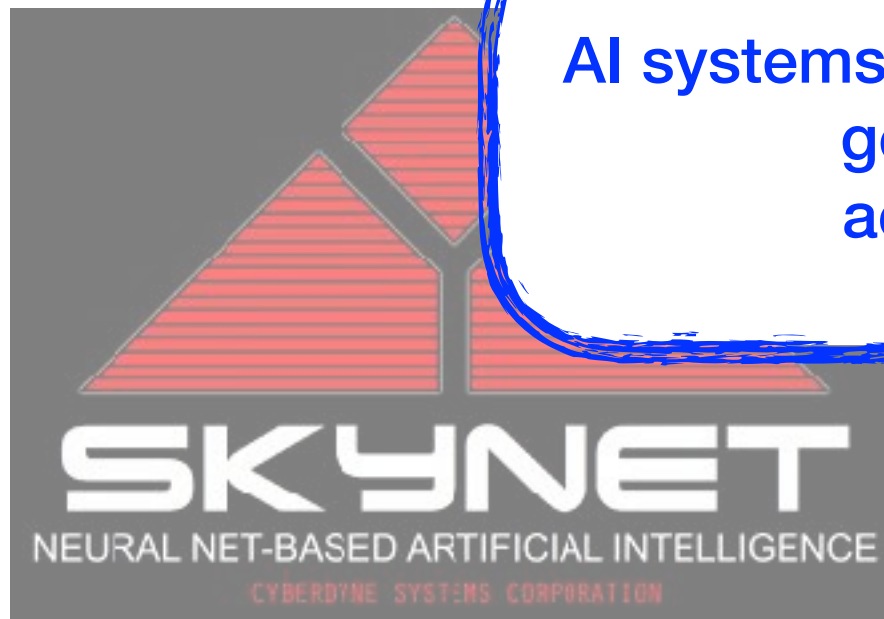


AI in science fiction

WOPR
(WarGames, 1983)



AI systems becoming too “intelligent” and self-aware;
getting out of control from humans;
acting against human will / interests



The Matrix
(1999)



Black Mirror
(2011)

Remarkable AI milestones

■ ELIZA (1964)

```
Welcome to

EEEEEE LL      IIII 2222222 AAAAA
EE      LL      II   22  AA  AA
EEEEEE LL      II   222  AAAAAA
EE      LL      II   22  AA  AA
EEEEEE LLLLLL IIII 2222222 AA  AA

Eliza is a mock Rogerian psychotherapist.
The original program was described by Joseph Weizenbaum in 1966.
This implementation by Norbert Landsteiner 2005.

ELIZA: Is something troubling you ?
YOU:  Men are all alike.
ELIZA: What is the connection, do you suppose ?
YOU:  They're always bugging us about something or other.
ELIZA: Can you think of a specific example ?
YOU:  Well, my boyfriend made me come here.
ELIZA: Is it important to you that your boyfriend made you come here ?
YOU:  He says I'm depressed much of the time.
ELIZA: I am sorry to hear that you are depressed.
YOU:  It's true. I am unhappy.
ELIZA: Can you explain what made you unhappy ?
YOU:  
```

■ IBM's Deep Blue beats Gary Kasparov in chess (1997)



■ Microsoft's Tay chatbot (2016)



Remarkable AI milestones

■ ELIZA (1964)

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■ IBM's Deep Blue Kasparov in 1997

Systems that “mimic” aspects of human intelligence (playing a game, having a conversation)



■ Microsoft's Tay chatbot (2016)



More down-to-earth “intelligent” systems

(Two examples from the networking world, ~1980)

- Distributed routing in the Internet

- Choosing the most appropriate data rate :
congestion control in TCP

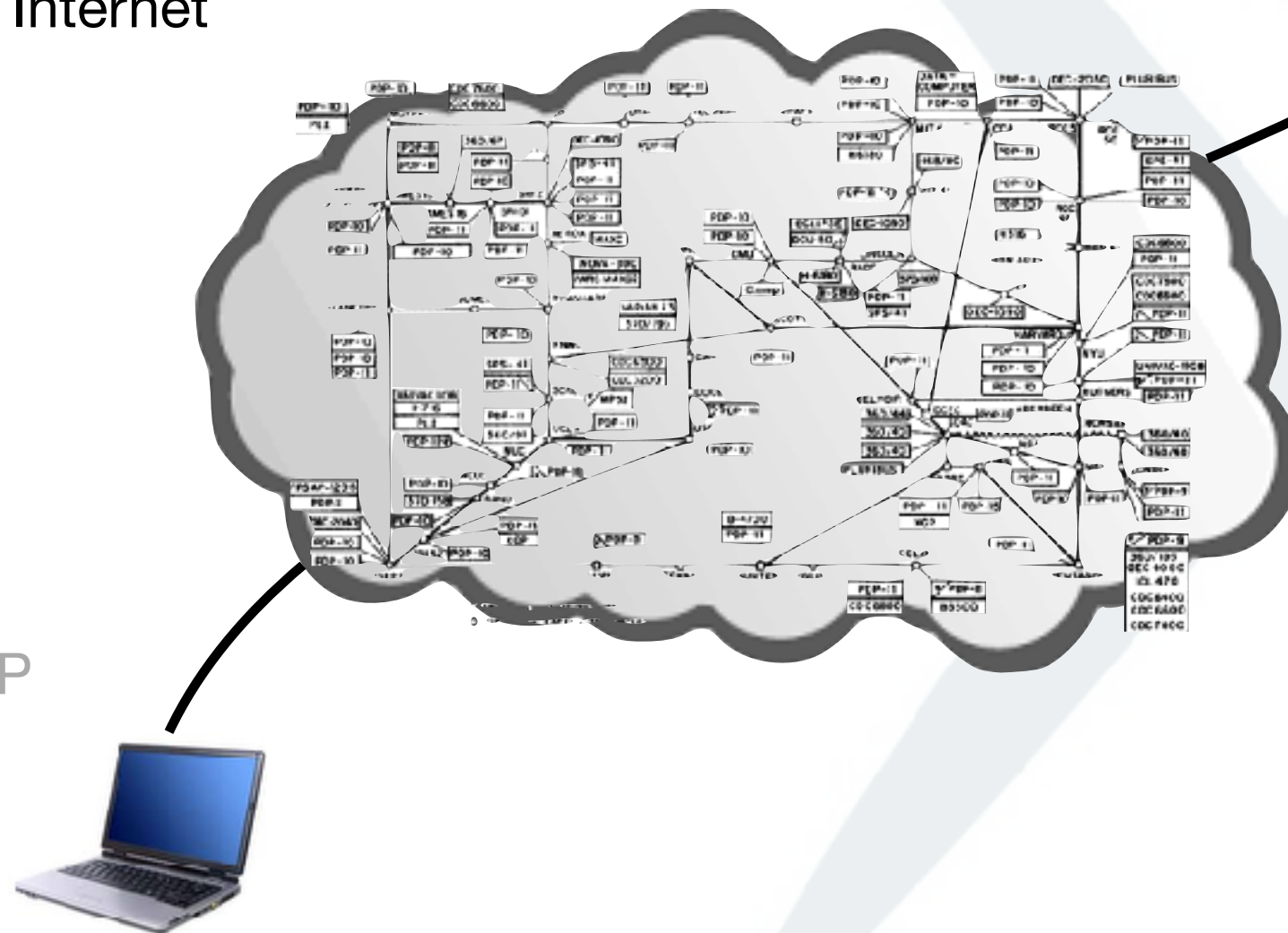


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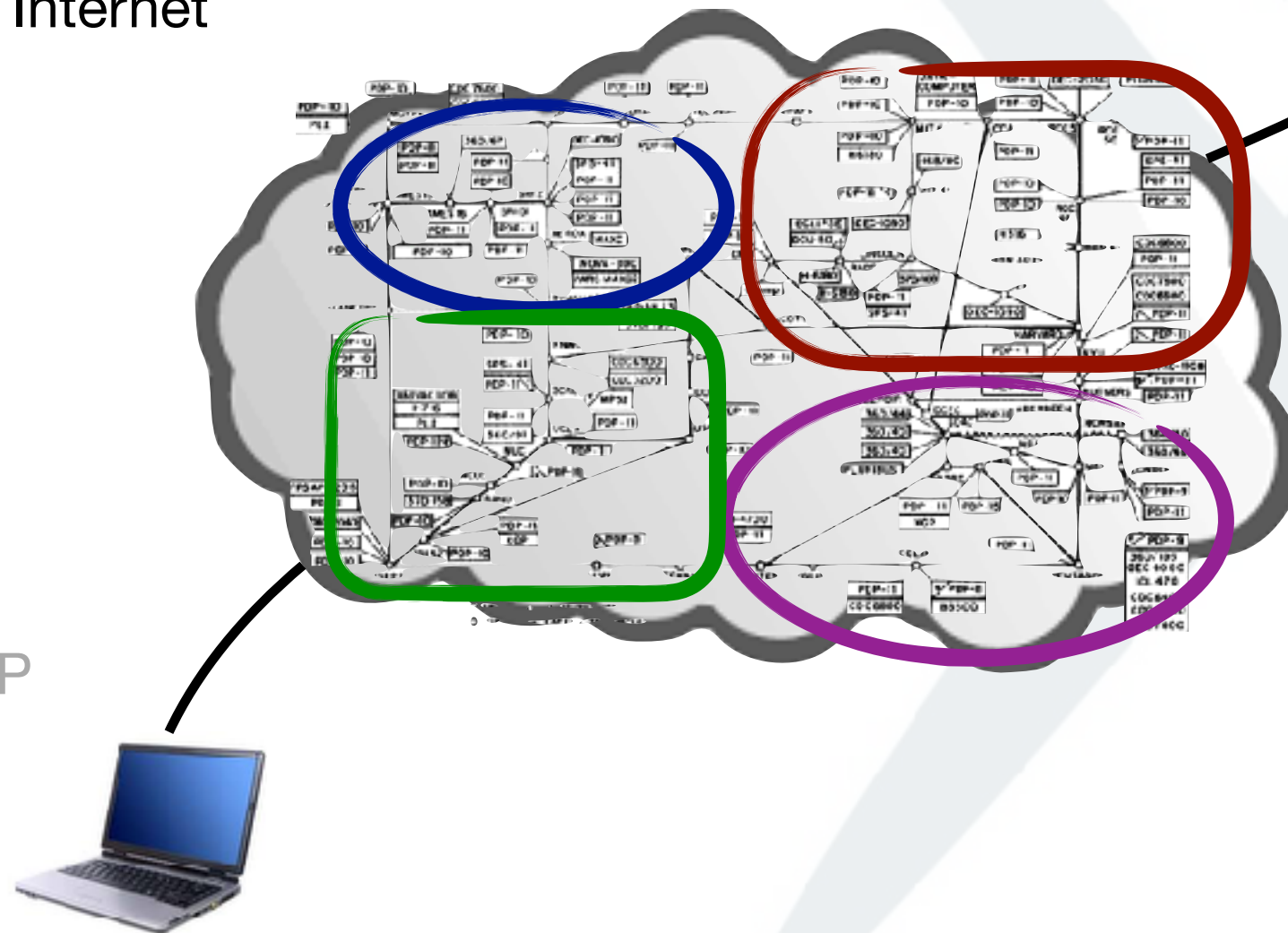


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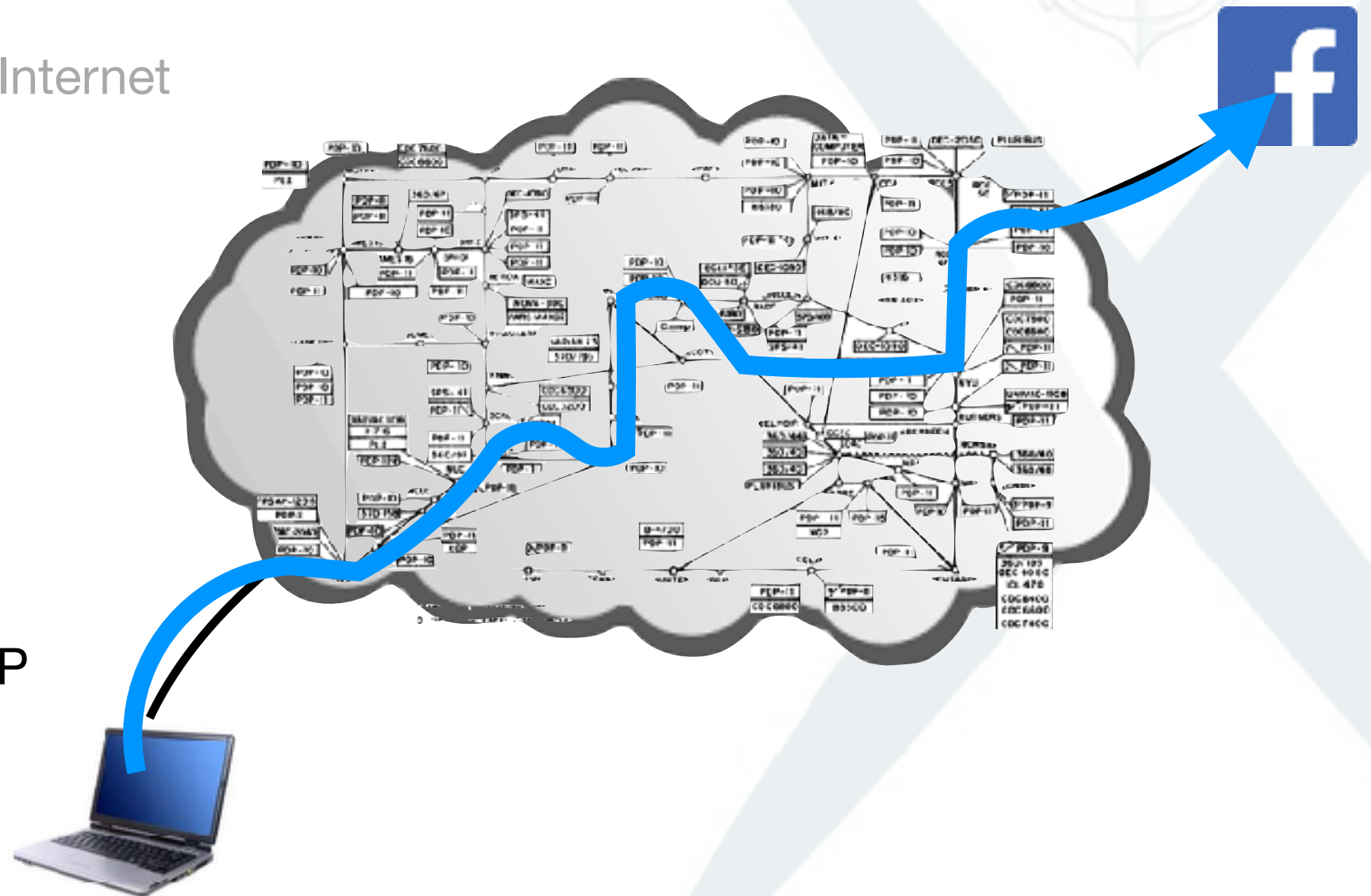


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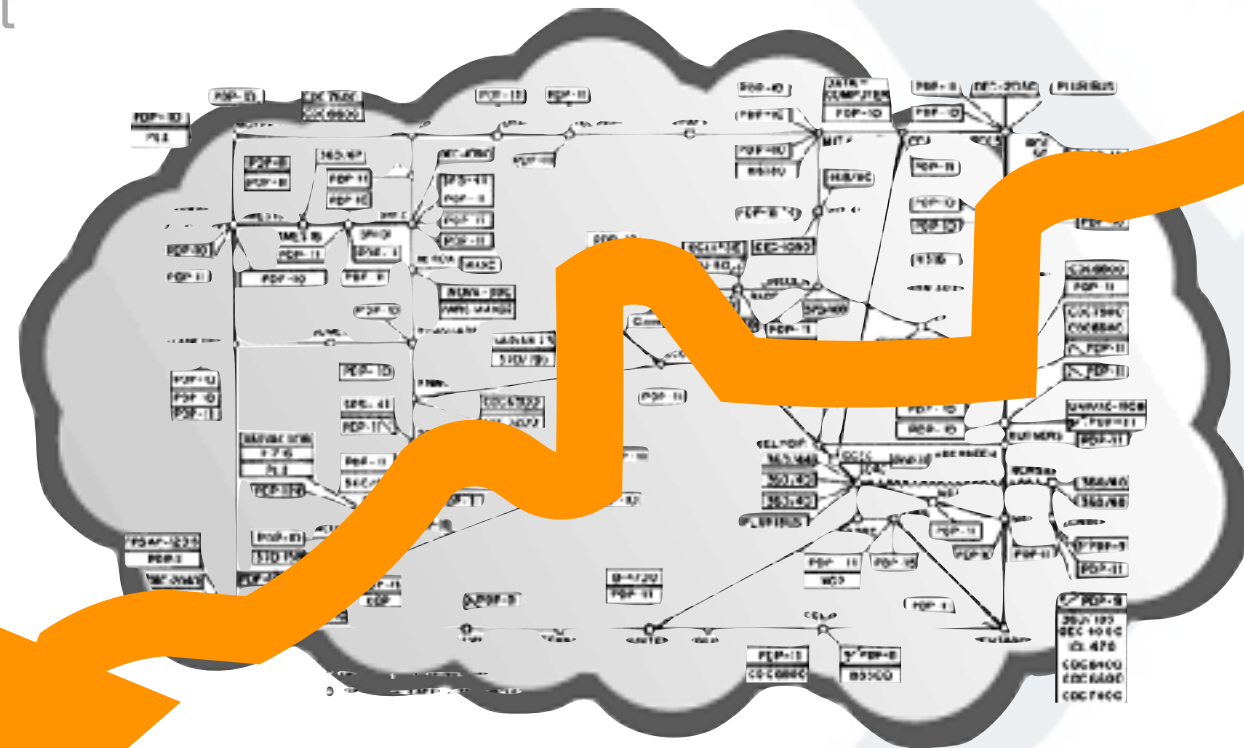


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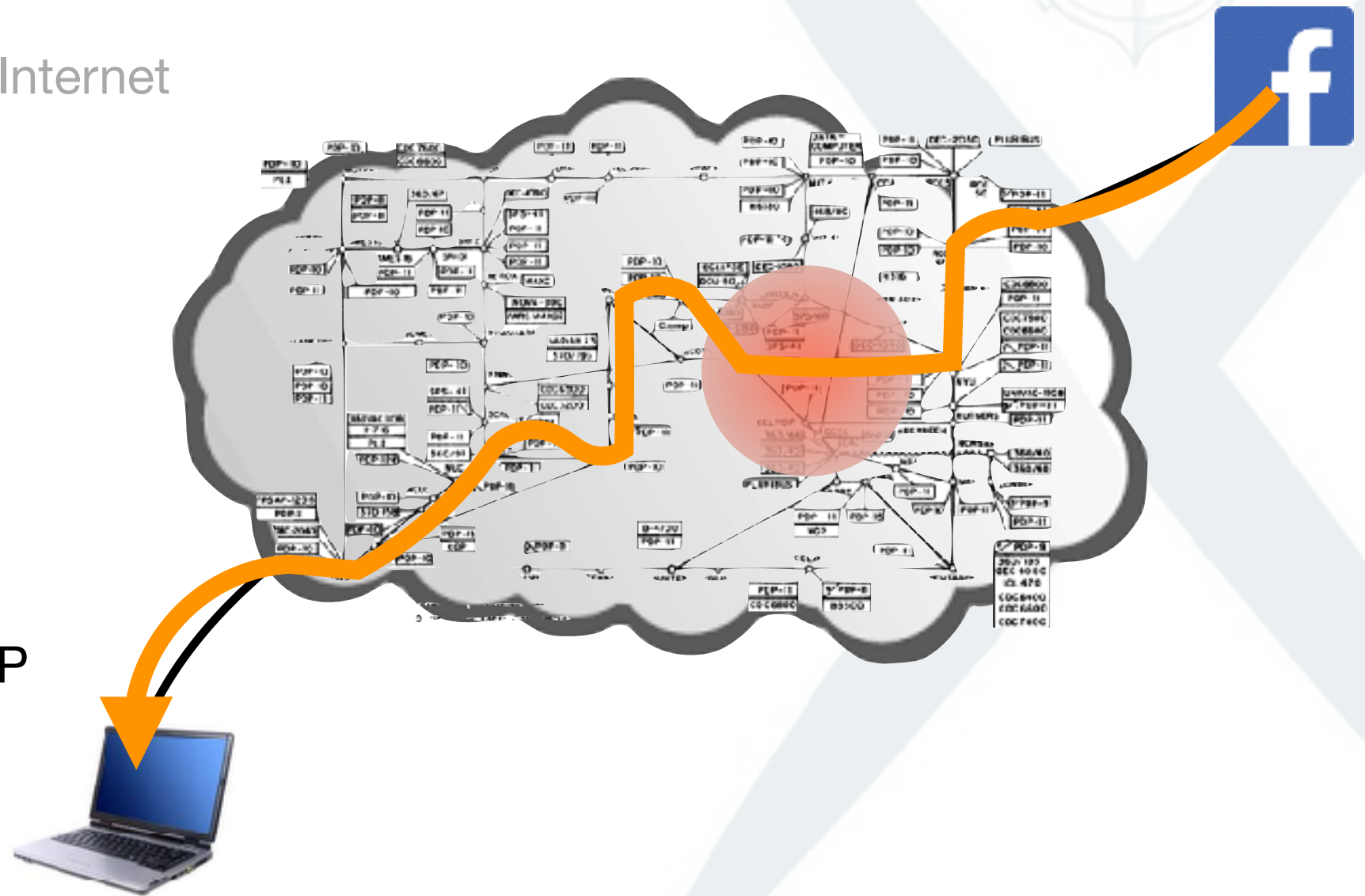


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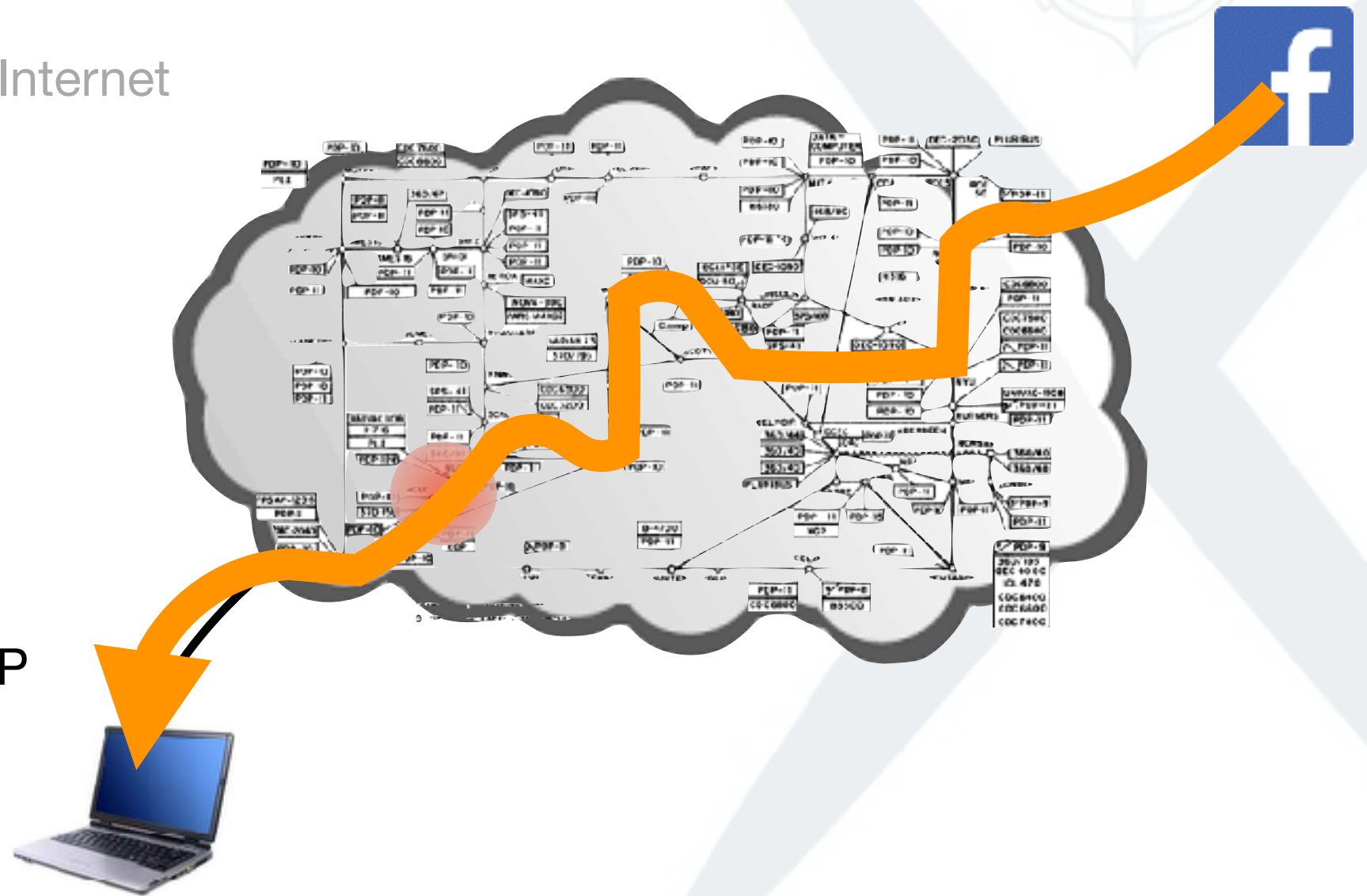


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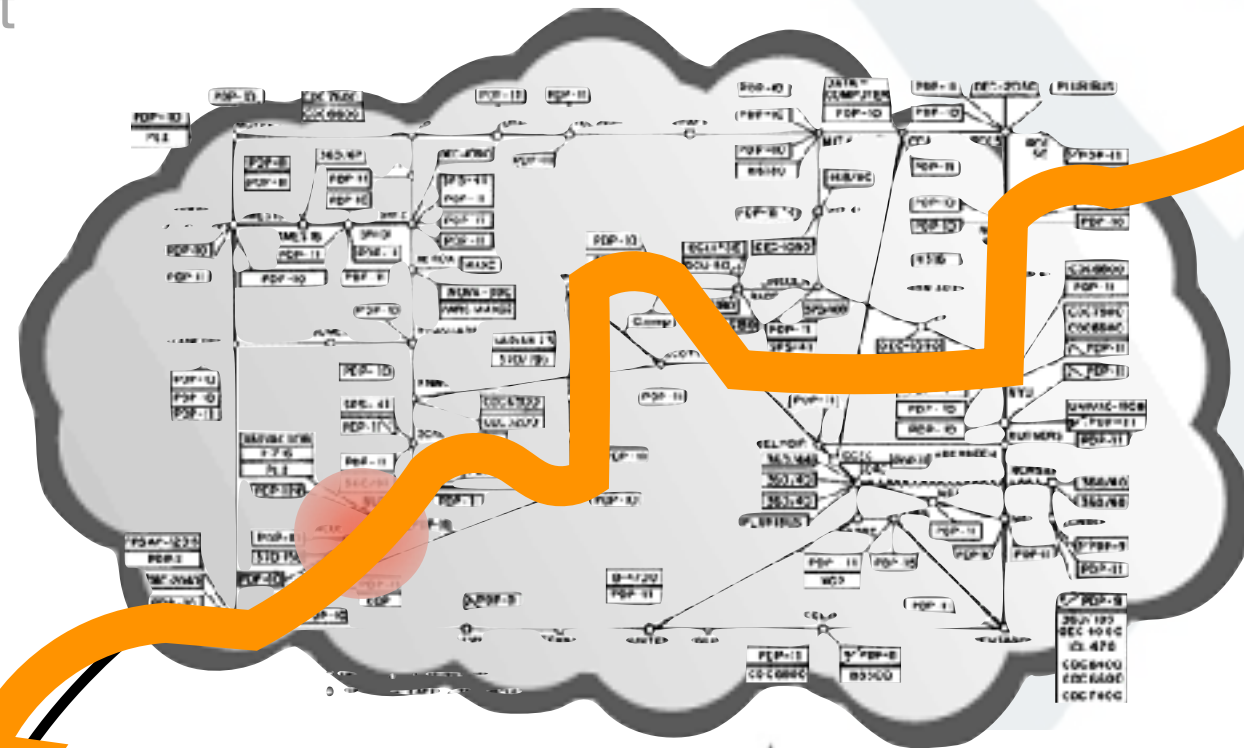
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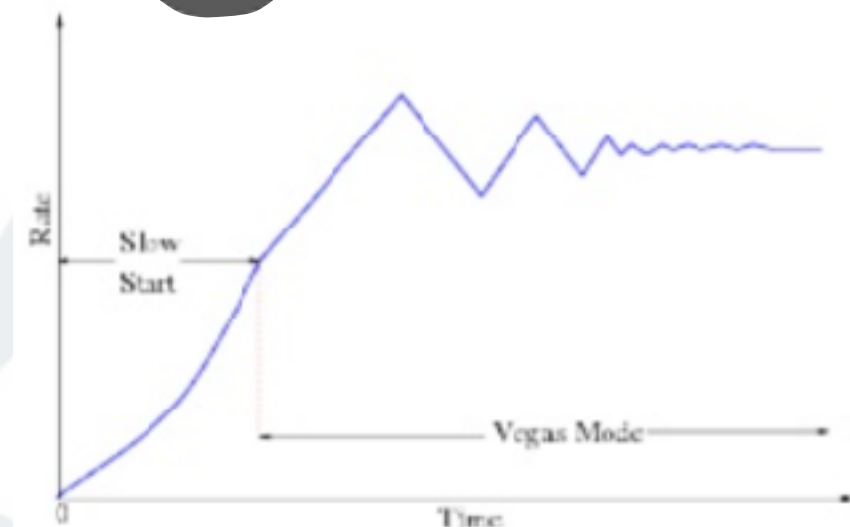
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■ Distributed routing in the Internet



■ Choosing the most appropriate **data rate** : congestion control in TCP



More down-to-earth “intelligent” systems

(Two examples from the networking world, ~1980)

■ Distributed routing in the Internet

- Complex, dynamic systems
- Multiple, uncoordinated agents
- Nobody knows everything
- Need to observe, exchange, learn & adapt

■ Choosing the most appropriate data rate : congestion control in TCP

*...are these “**intelligent**” ?*

(...certainly not new)

What is “intelligence” ?

- *Philosophical / psychological open question*
- Ability to **remember** ?
- Ability to **perceive** the environment ?
- Ability to **adapt** to the environment ?
- Ability to **learn** ?
- Ability to **solve** problems ?
- Ability to **reason** ?



Intelligence *et caetera*

■ A few definitions

Turing test: it is intelligent what
“**looks**” (humanly) intelligent (1950)

“...ability to **understand** complex ideas, to **adapt** effectively to the environment, to **learn** from experience, to engage in various forms of **reasoning**, to overcome obstacles by taking thought...” (APA, 1995)

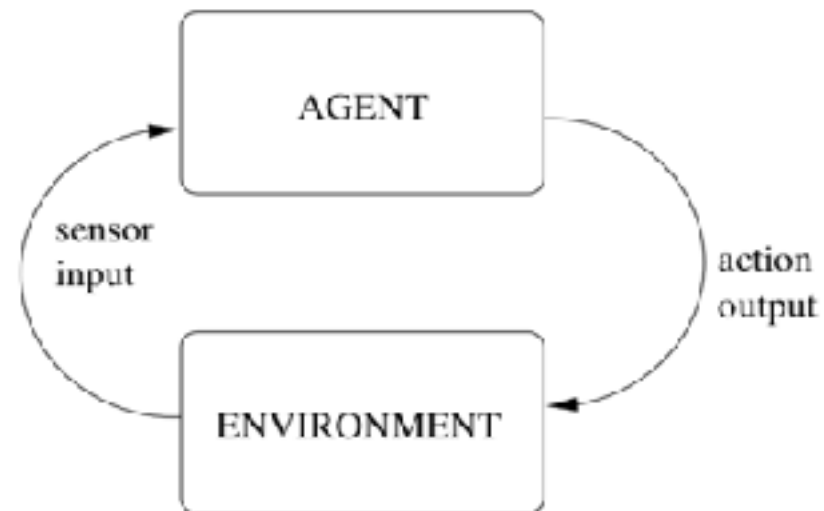
“goal-directed **adaptive** behavior”
(R. J. Sternberg and W. Salter, 1982)

“...the resultant of the process of **acquiring, storing** in memory, retrieving, **combining, comparing**, and using in **new contexts** information and conceptual skills”
(LI. Humphreys, 1979)

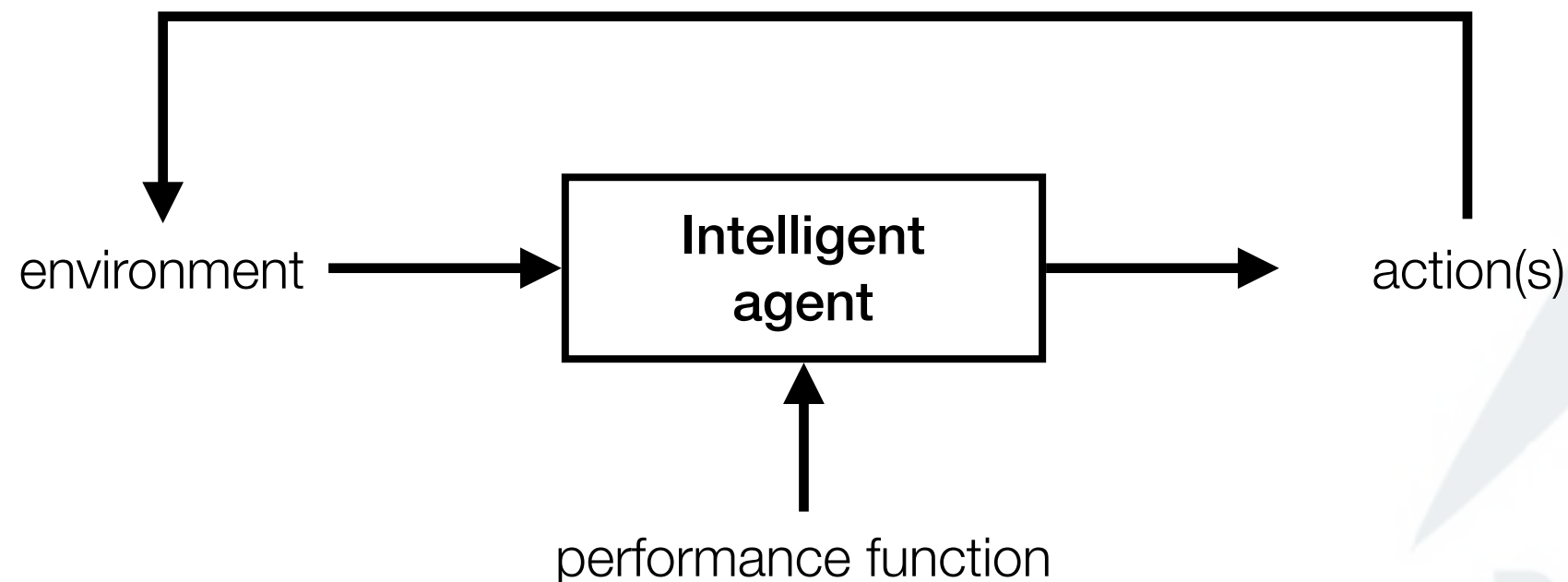


Intelligence *et caetera*

■ ...we'll be a bit more humble...

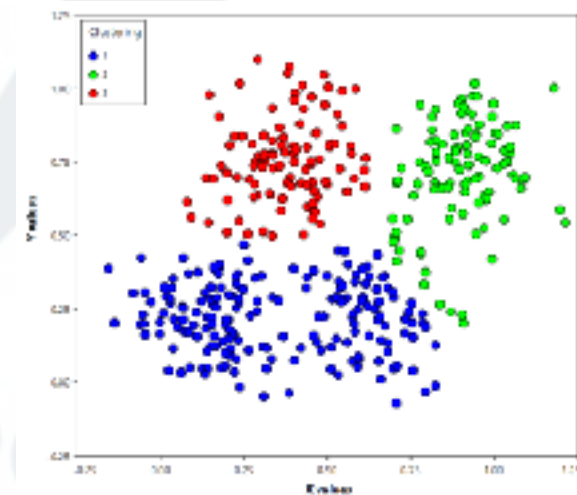
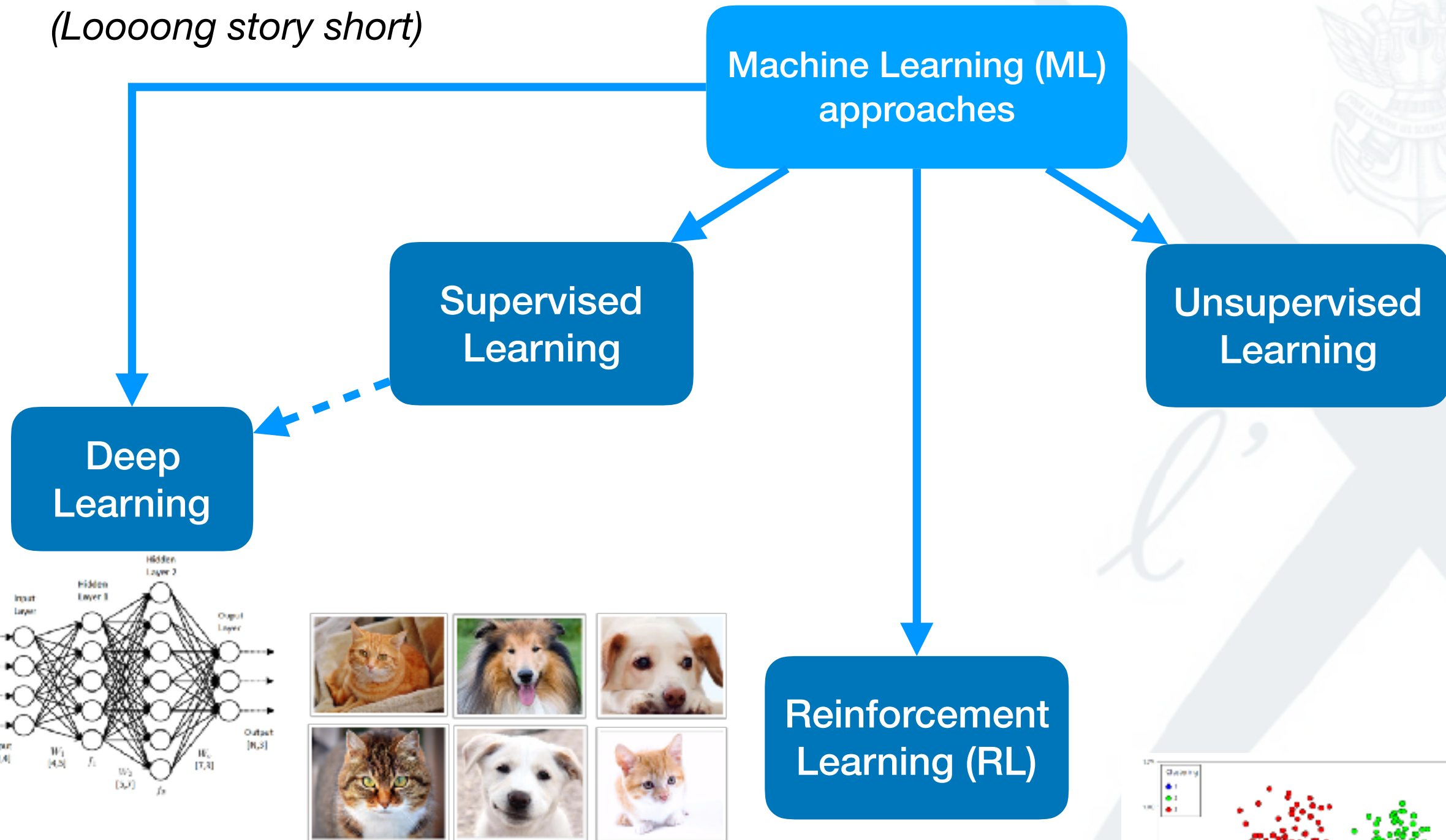


Intelligent agents: entities **perceiving** and **acting** on a (highly **dynamic**) environment, able to **learn (adapt)** in order to maximize a **performance measure**



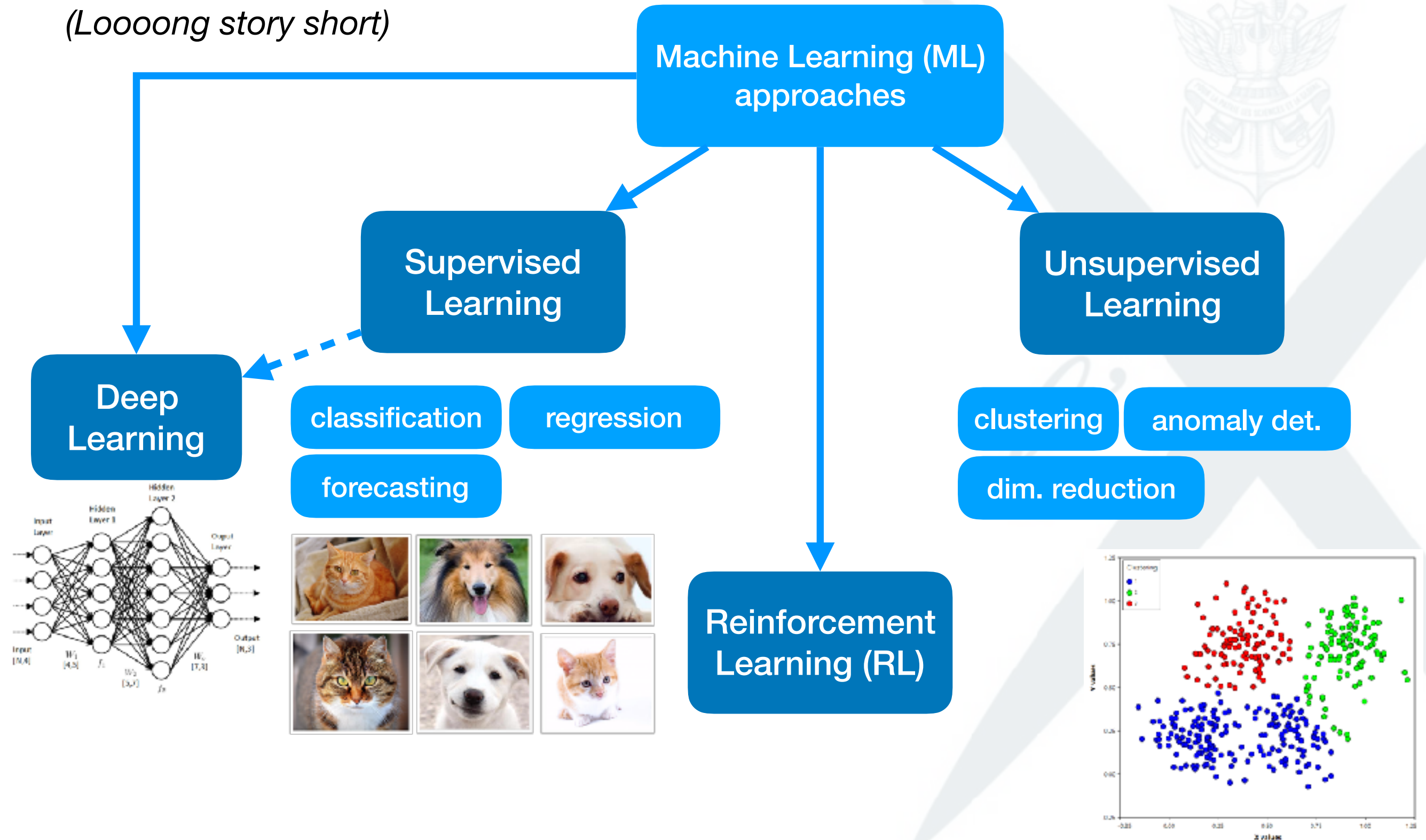
How do machines learn ?

(Looooong story short)



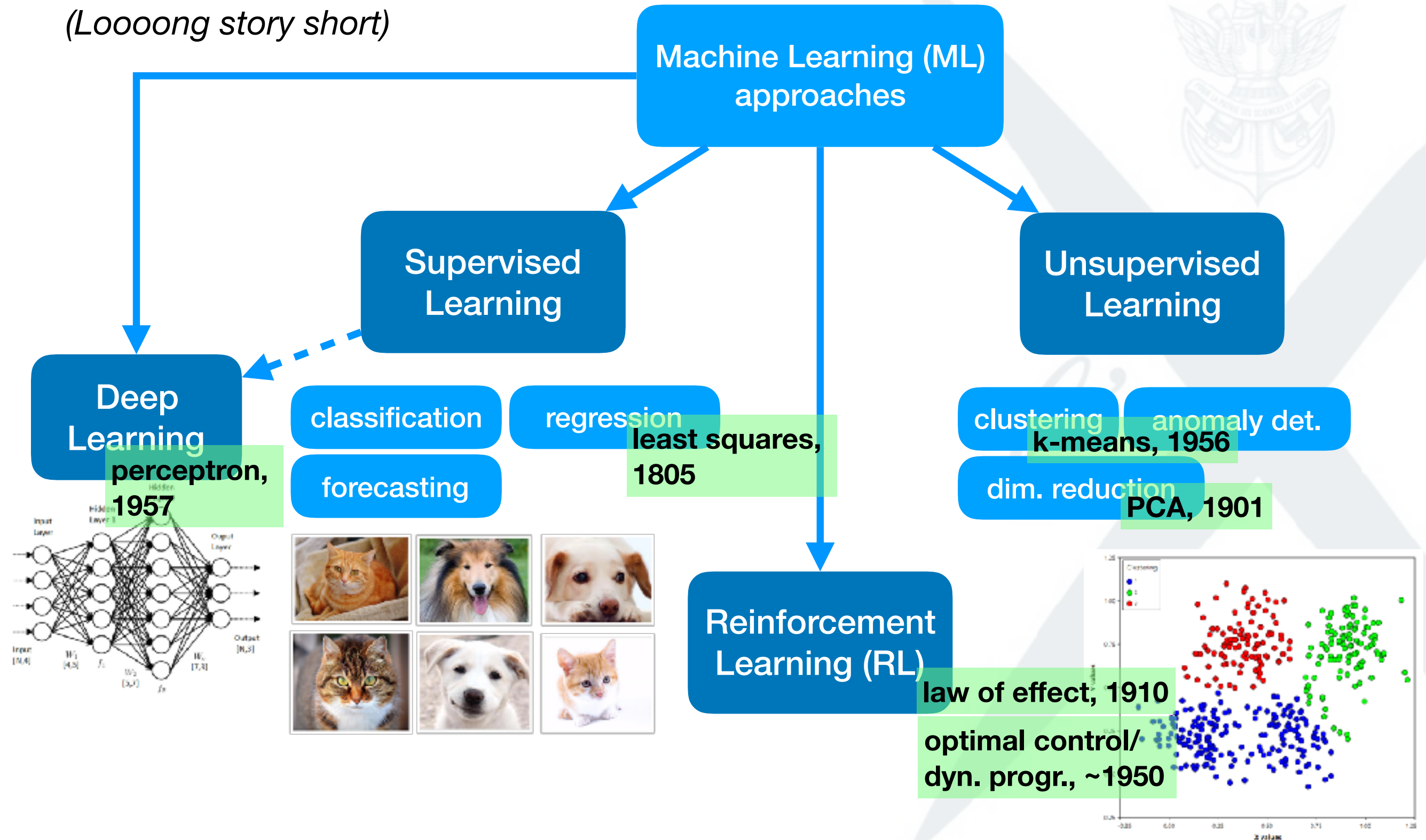
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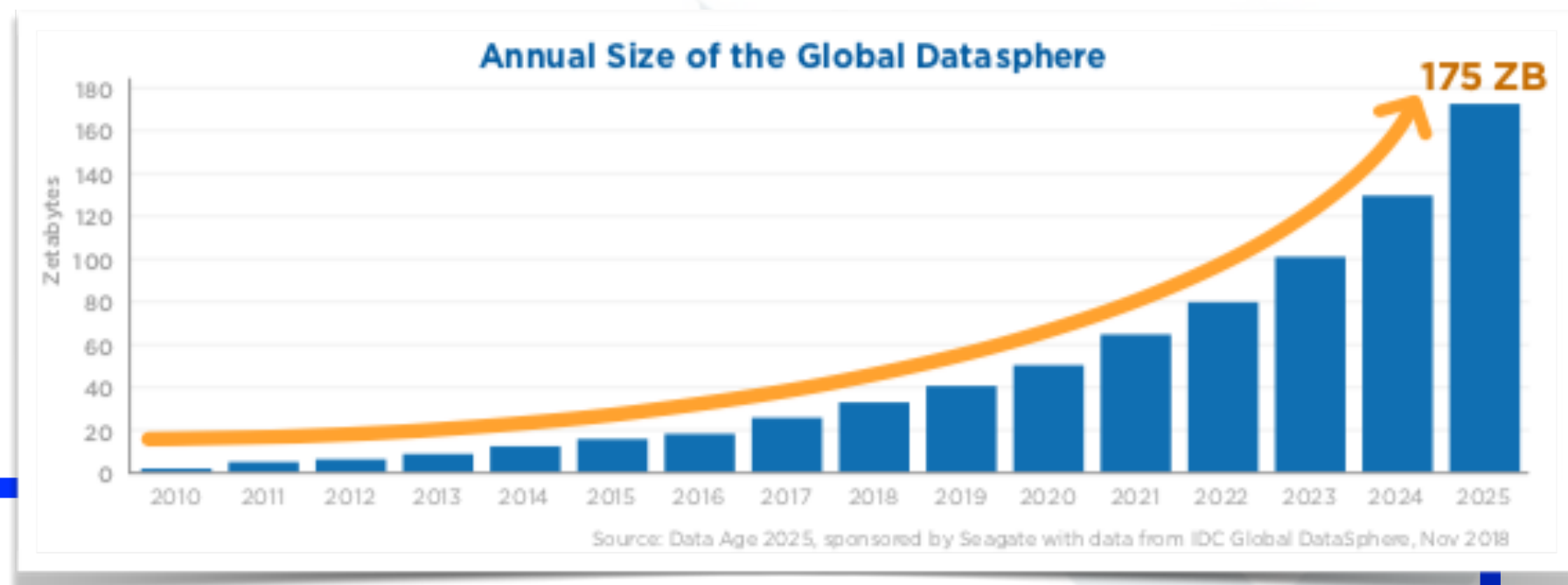


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What is new about all this?

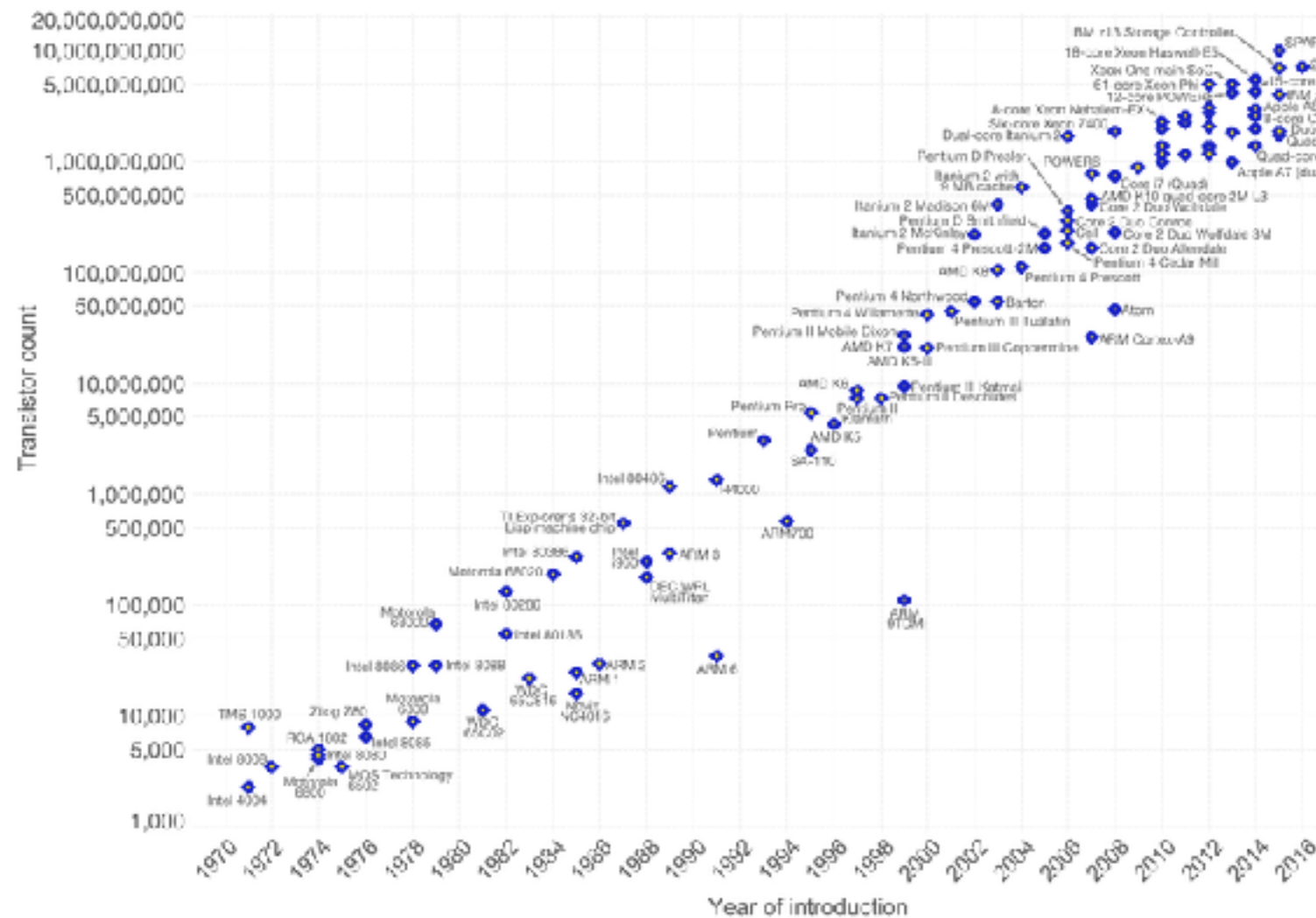


What is new is the
scale



*What is new is the **scale***

■ Moore's law (empirical observation)



Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)

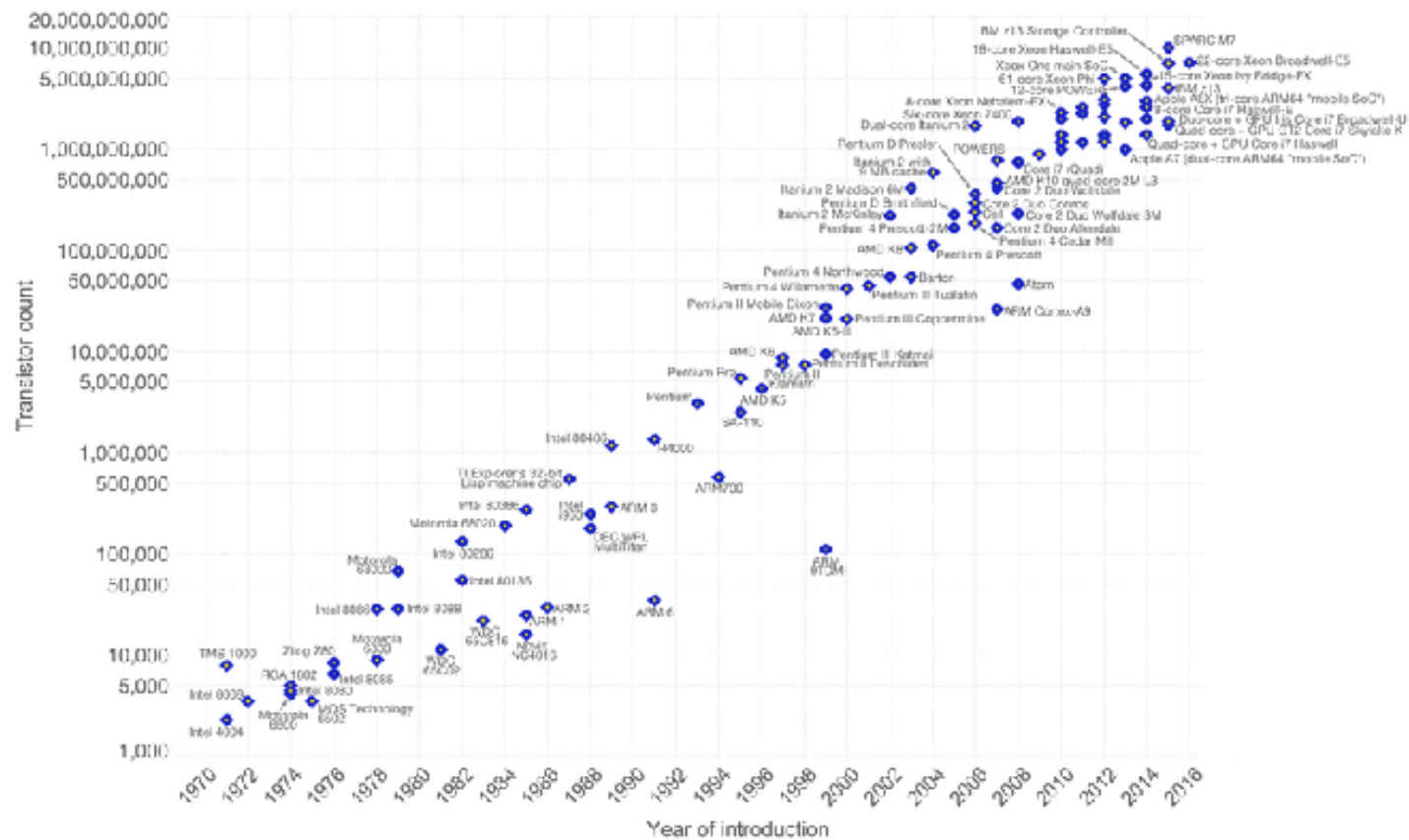
The data visualization is available at [OurWorldinData.org](https://ourworldindata.org). There you find more visualizations and research on this topic.

Licensed under [CC-BY-SA](#) by the author Max Flosser

*“computing capacity (or # transistors per IC) **duplicates** roughly **every 2 years**”*

*What is new is the **scale***

■ Moore's law (empirical observation)



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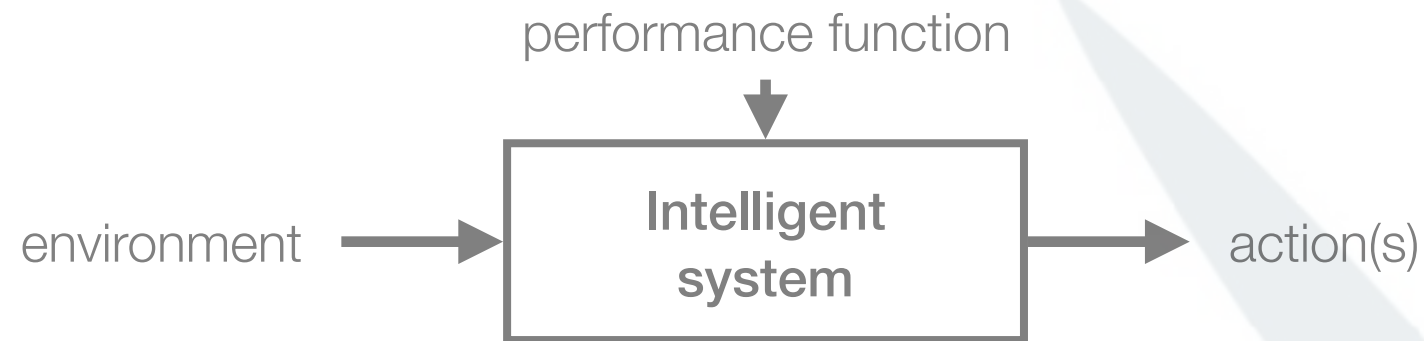
IOT

produce / transport data...

Big Data

...and process data

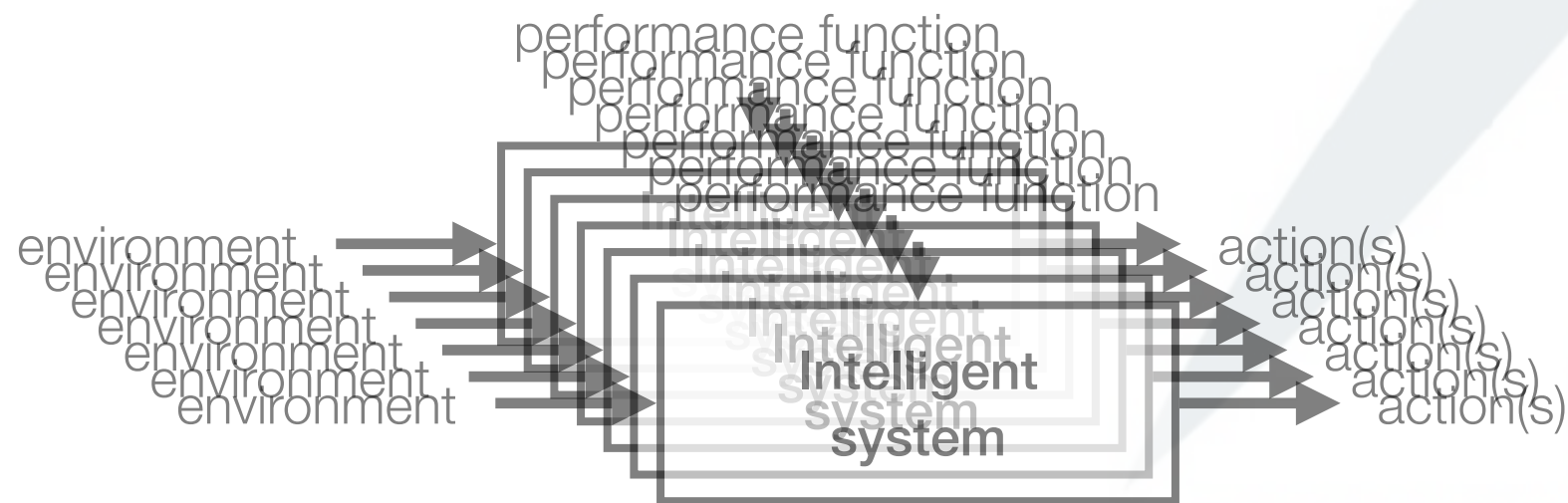
Implications



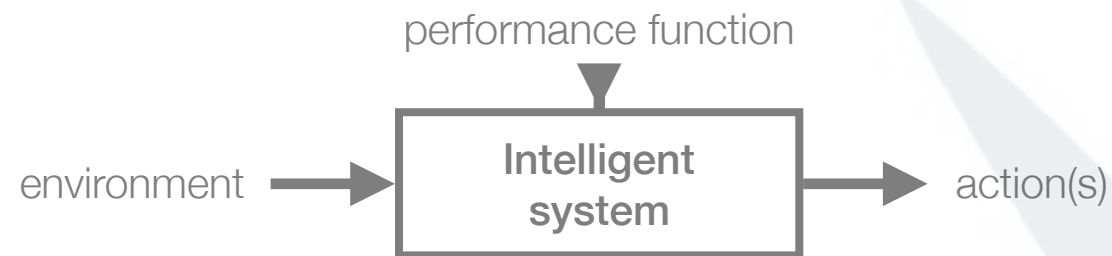
Intelligent systems



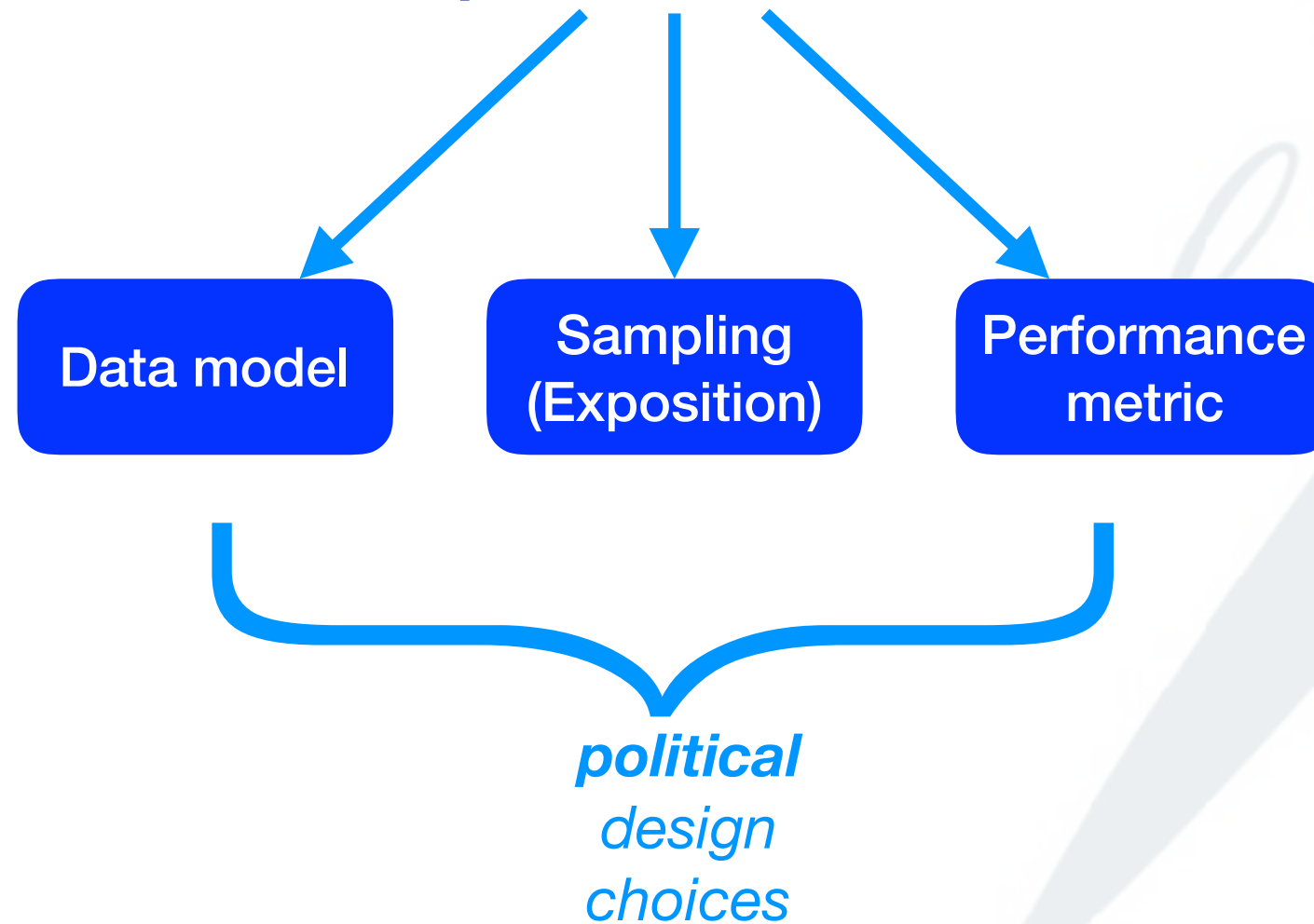
Intelligent ***connected*** systems



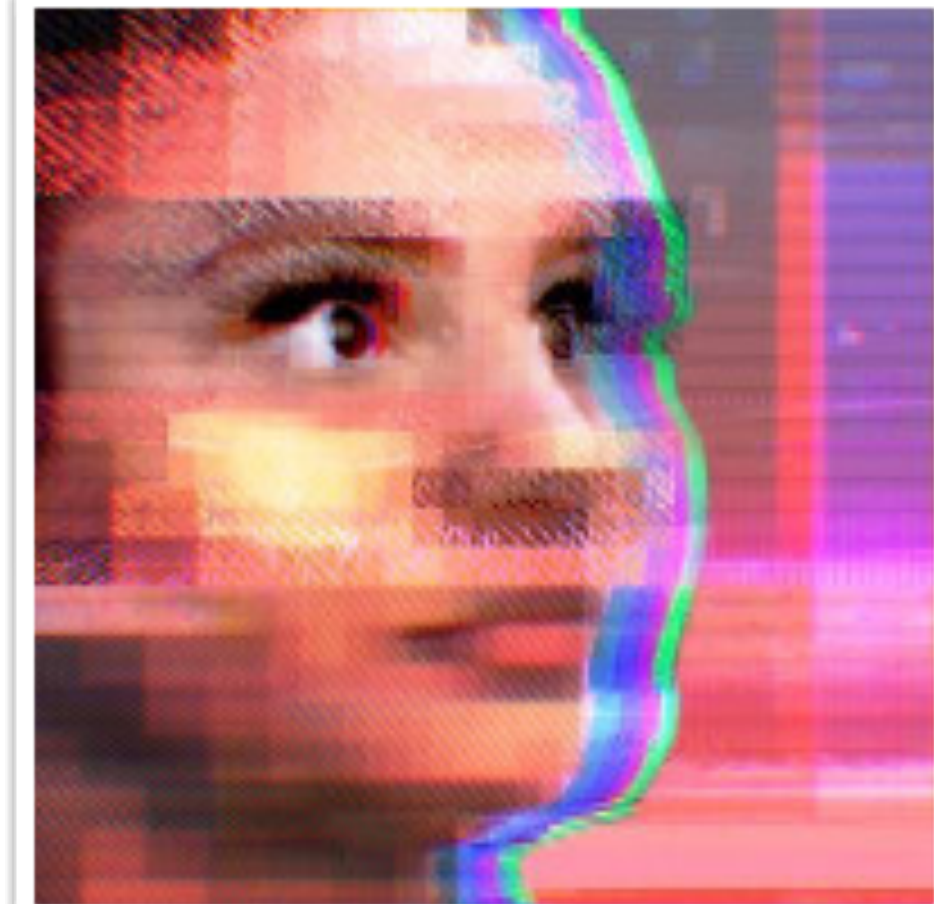
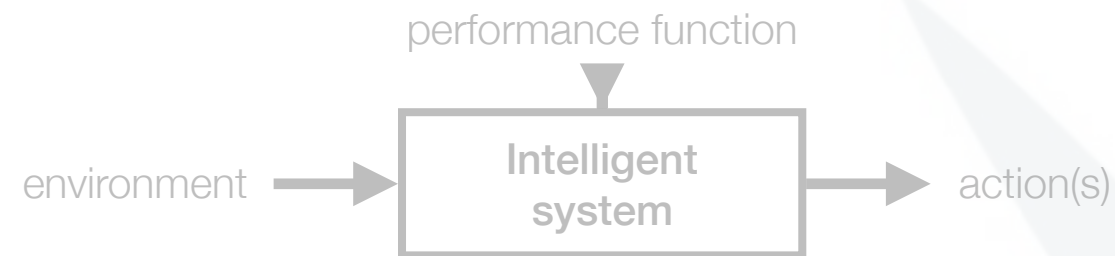
Data centrality



Intelligent systems heavily depend on
provided data



Data centrality



t systems
provide

Sam
(Expo



*political
design
choices*

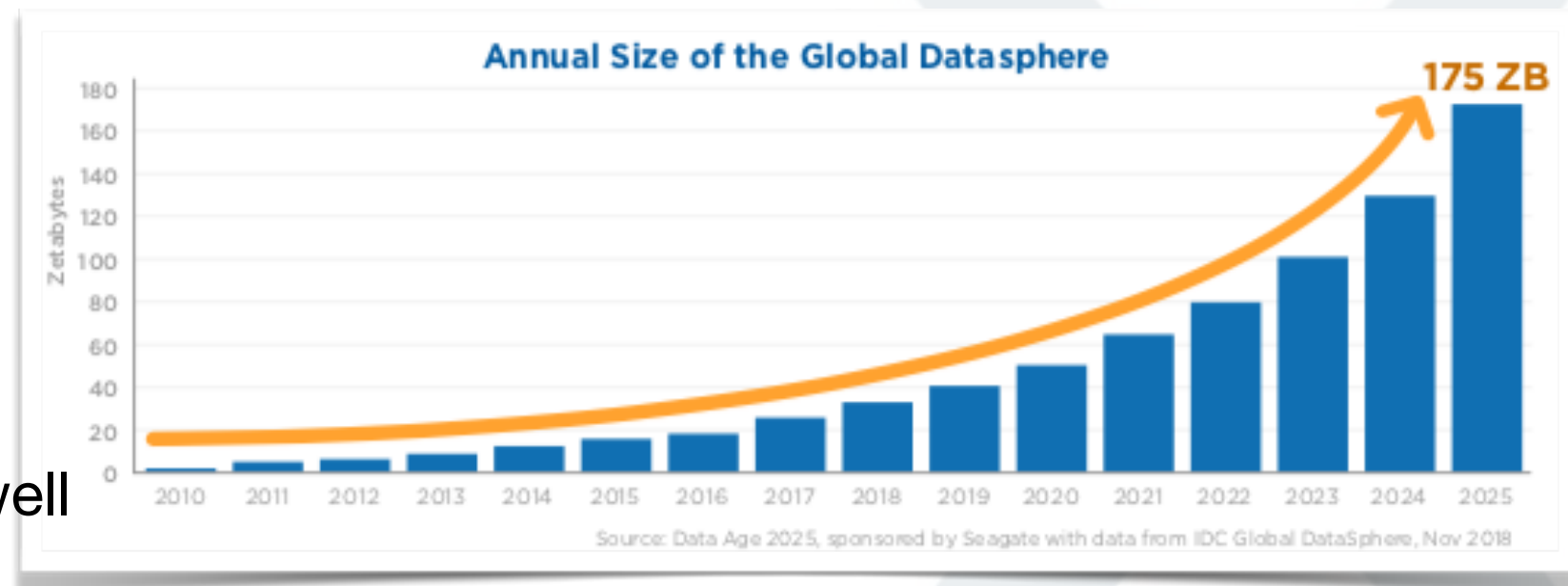
Data centrality : the power of aggregation

Intelligent **connected** systems :
intelligent (mostly) **because** connected



■ Towards a **data-driven** economy (...and society?)

- Digital economy business models increasingly rely on data flow exploitation
- “Smart” **public** services and infrastructures do as well



■ **Exponential** growth

- “90% of total data has been generated in last 2 years” (IBM)

■ Privacy, ownership, **retribution**

- European-centric concern ?

Enabling technologies & infrastructures

Intelligent **connected** systems :
(only) as robust as their underlying network

- (Many) new features are achieved at the cost of a higher dependency on enabling technologies
=> new vulnerabilities
- Enabling technologies for **transport**, **storage**, **processing** of data in/towards intelligent systems
 - **Internet**: not conceived to become this big
=> insecure
 - **IOT** systems are typically not designed with security in mind
 - **Datacenters**: if they go down, services are likely to follow



Underwater Internet cable repair



Telefónica datacenter, Alcalá de H., Madrid, Spain

Enabling technologies & infrastructures

Intelligent **connected** systems :
(only) as robust as their underlying network

- Systems **integration** : pre-existing communication systems (television, telephone) are becoming part of (or dependent on) the Internet
 - As well as **critical infrastructures** for society (energy grid, smart cities, transportation systems, connected healthcare)
- If you are **connected**, you are **exposed**
- What if not available? => “**graceful downgrading**”
 - ...when it's smart to play dumb

Massive Google Outage Turned Smart Homes Into Zombies

Users reported doors, baby monitors, and thermostats going kaput. The Internet of Things is convenient—until there's no Internet.



Kelly Weill
Reporter

Updated 06.03.19 4:37PM ET / Published 06.03.19 2:56PM ET



Your smart home is only as smart as the network that runs it.

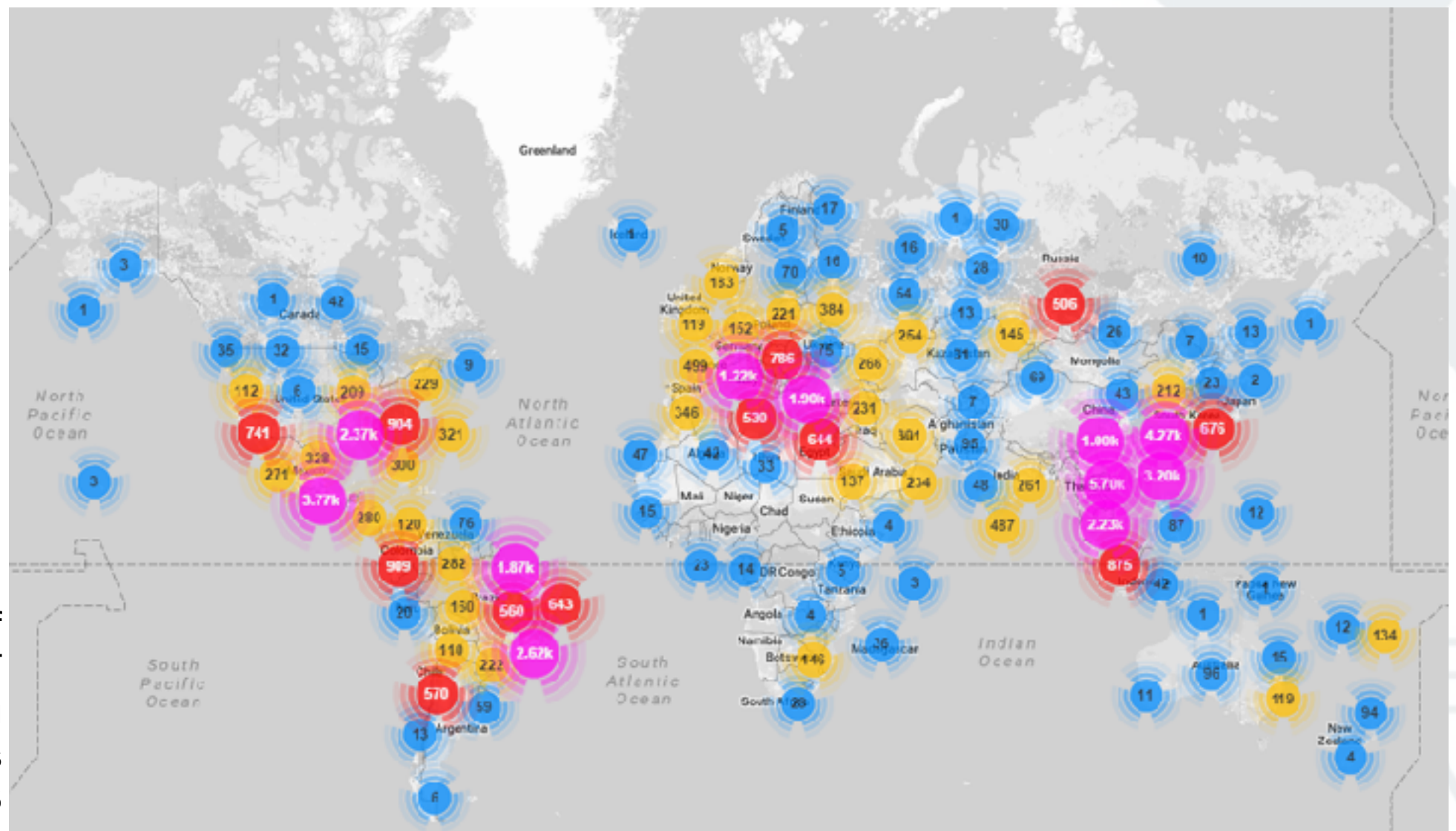
On Sunday, some Google users found themselves locked out of YouTube and Gmail as the tech giant experienced major outages across the U.S. But while the service disruption only affected most users' browsing history, others saw their homes malfunction. Nest, a Google-owned smart home company, was also affected by the outage. For Nest users, that meant losing access to smart thermostats, smart baby monitors, and smart front doors.

Enabling technologies & infrastructures

- Internet + IOT => **cybersecurity risks**
- “intelligent connected systems” may be not only targets... but also **unwilling agents** of cyberattacks !
- Example : **Mirai** DDoS ciberattack against Dyn (Sept. 2016)
 - Millions of users affected, ~50K IOT devices involved



Distribution of
compromised IOT
devices taking
part in Mirai's
botnet DDoS



Further (social) considerations : looking ahead

■ **Human augmentation or substitution ?**

- Political choice, in part
- Actual responsibility on system's outcomes ?

■ **Distributed vs centralized systems**

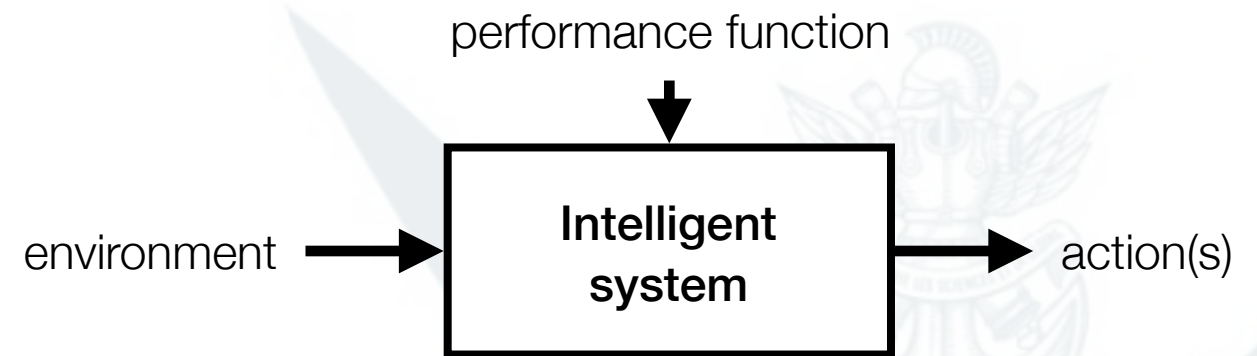
- trade-off between centralization and distribution
- single vs multiple points of failure
- local optimization \neq global optimization
- complex interaction of different intelligent systems (Internet, autonomous vehicles)
- stability, predictability, oscillations, troubleshooting

■ **Towards which kind of world ?**

- Human systems (cities...) become heavily dependent of now-critical technologies
 - (...as it happened in the past: electricity, car)
- These technologies will generate (are generating) a “new world” around them
 - **Public regulation** and issues: net neutrality, common carriers
 - Access inequalities (e.g. 5G)
- “Understandability” of involved systems
 - What is not (minimally) understood is potentially feared

Take-aways

- Most urgent challenges derived from AI emergence **don't necessarily come** from where we may expect
- Intelligent connected systems
 - **Interaction** with the environment
 - Intelligent **because** (massively) connected
- “Smart” services are (mostly) **dependent** on ever-increasing **data flows** (for training, learning, monitoring, etc.) and **large-scale connectivity** (Internet + IOT)
- Enabling infrastructures & technologies have become **socially critical**
 - Classical challenges: to **access inequality**, infrastructure **ownership/regulation**, innovation enabling, required **qualifications** to interact with the resulting world
- “Smart” systems are exposed to **new vulnerabilities**
 - Connected => exposed
 - Need to integrate “**graceful downgrading**” in designs





Thank you !

juan-antonio.cordero-fuertes@polytechnique.edu

References

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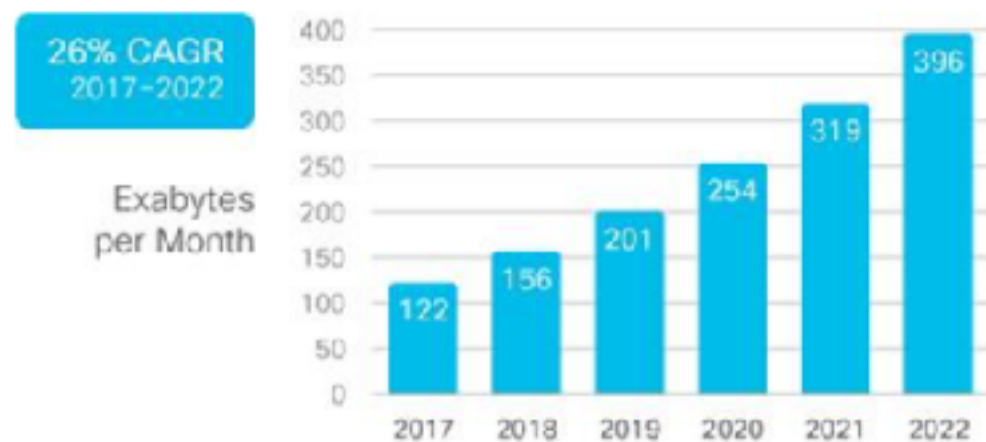
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ÉCOLE
POLYTECHNIQUE

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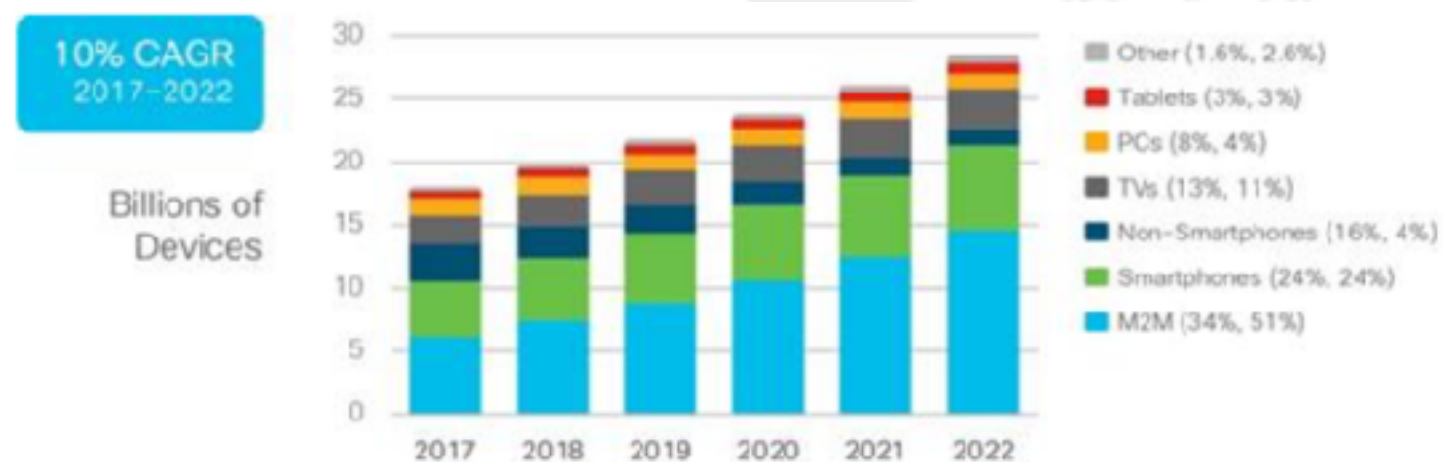
*What is new is the **scale***

Internet (IP) traffic

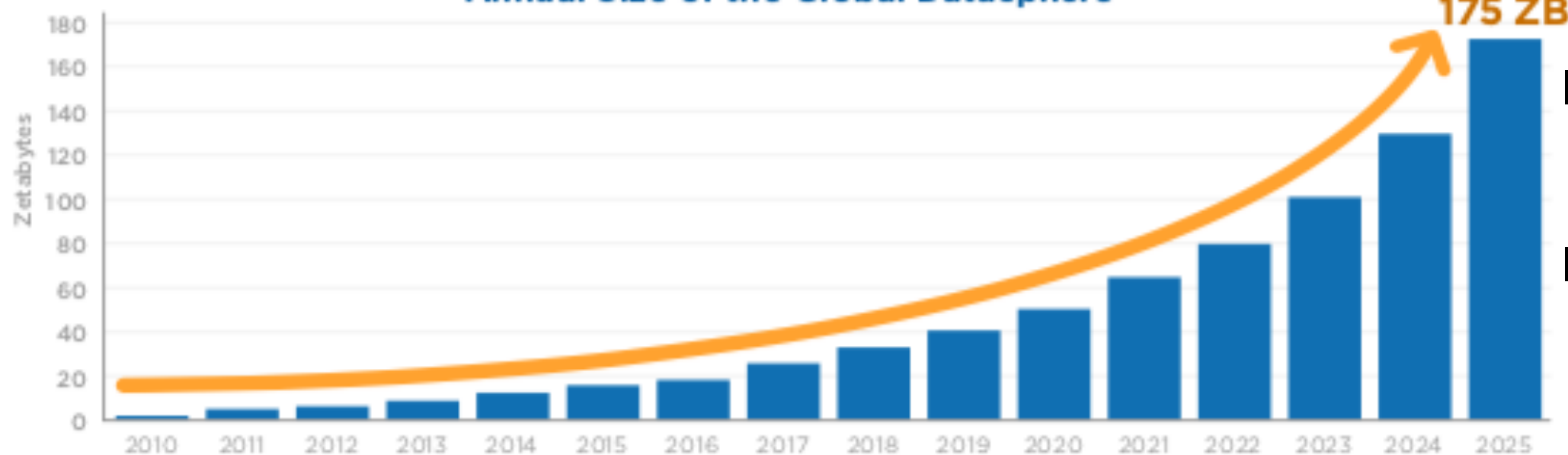


Cisco VNI Global IP Traffic Forecast (2019)

Internet size (# connected devices)



Annual Size of the Global Datasphere



Source: Data Age 2025, sponsored by Seagate with data from IDC Global DataSphere, Nov 2018

■ ~30 billion devices
in 2022

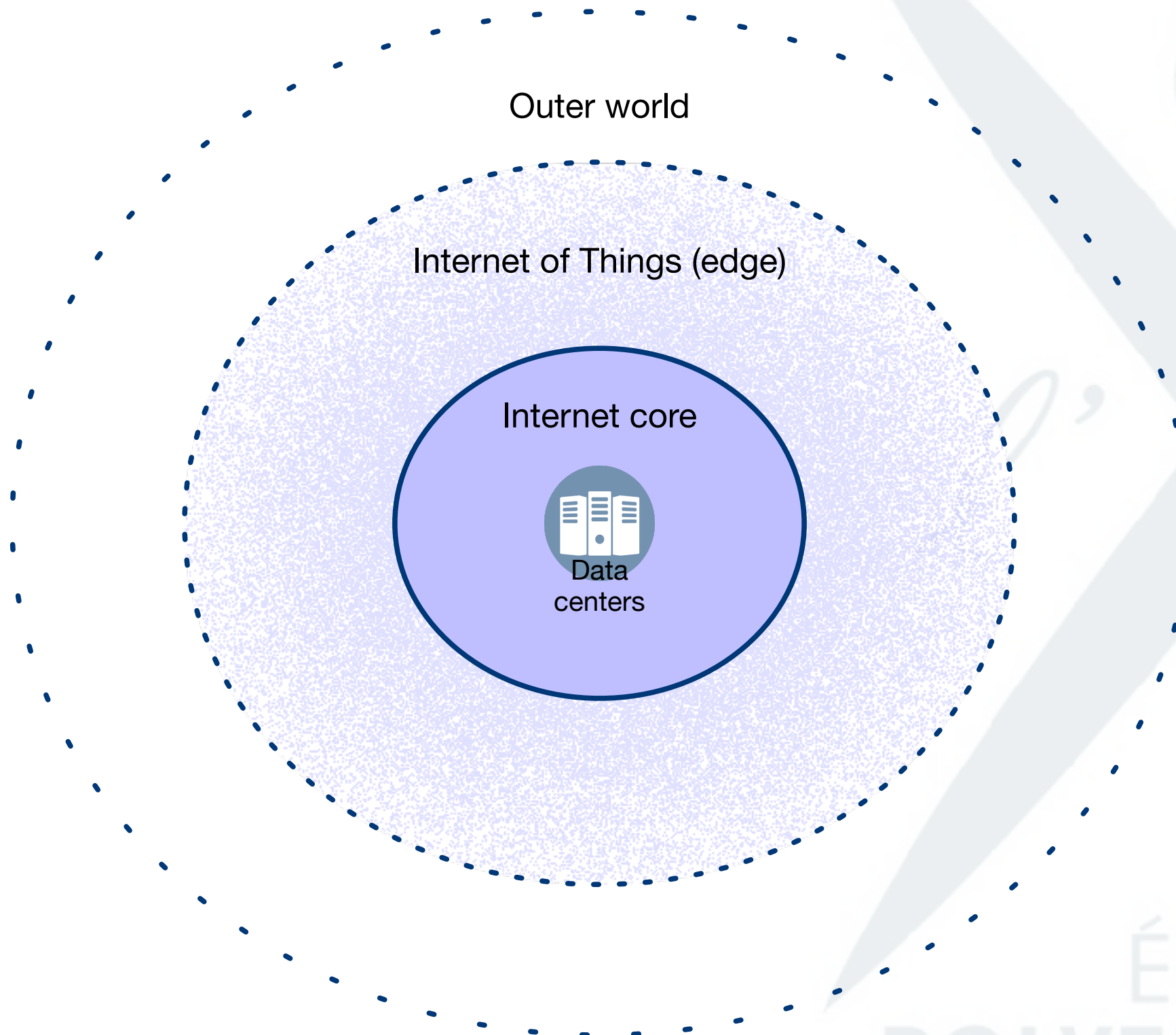
■ ~400 EB (10^{18} B)
per month in 2022

■ ~175 TB (10^{21} B) in
the datasphere in
2025

■ **Exponential**
increase expected

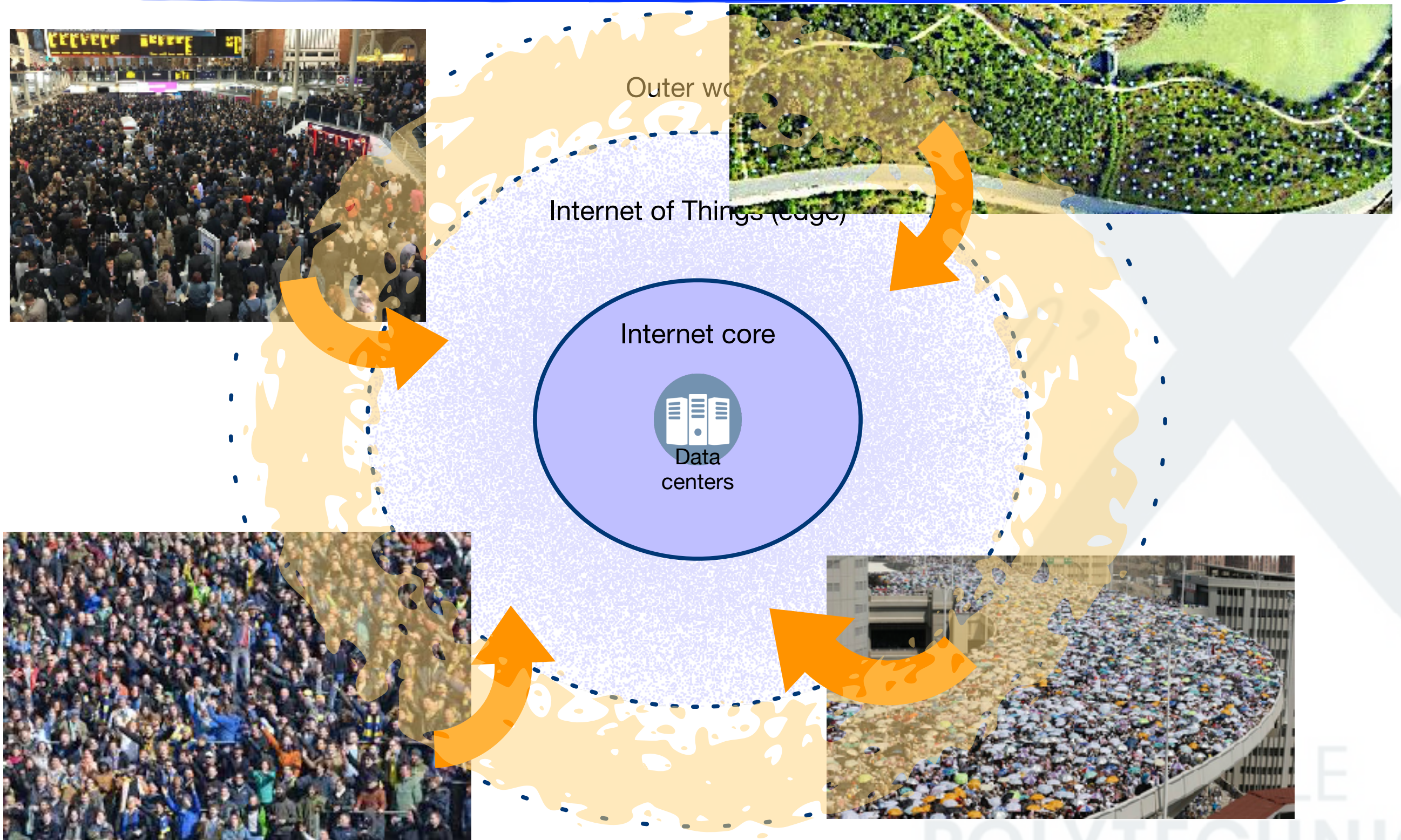
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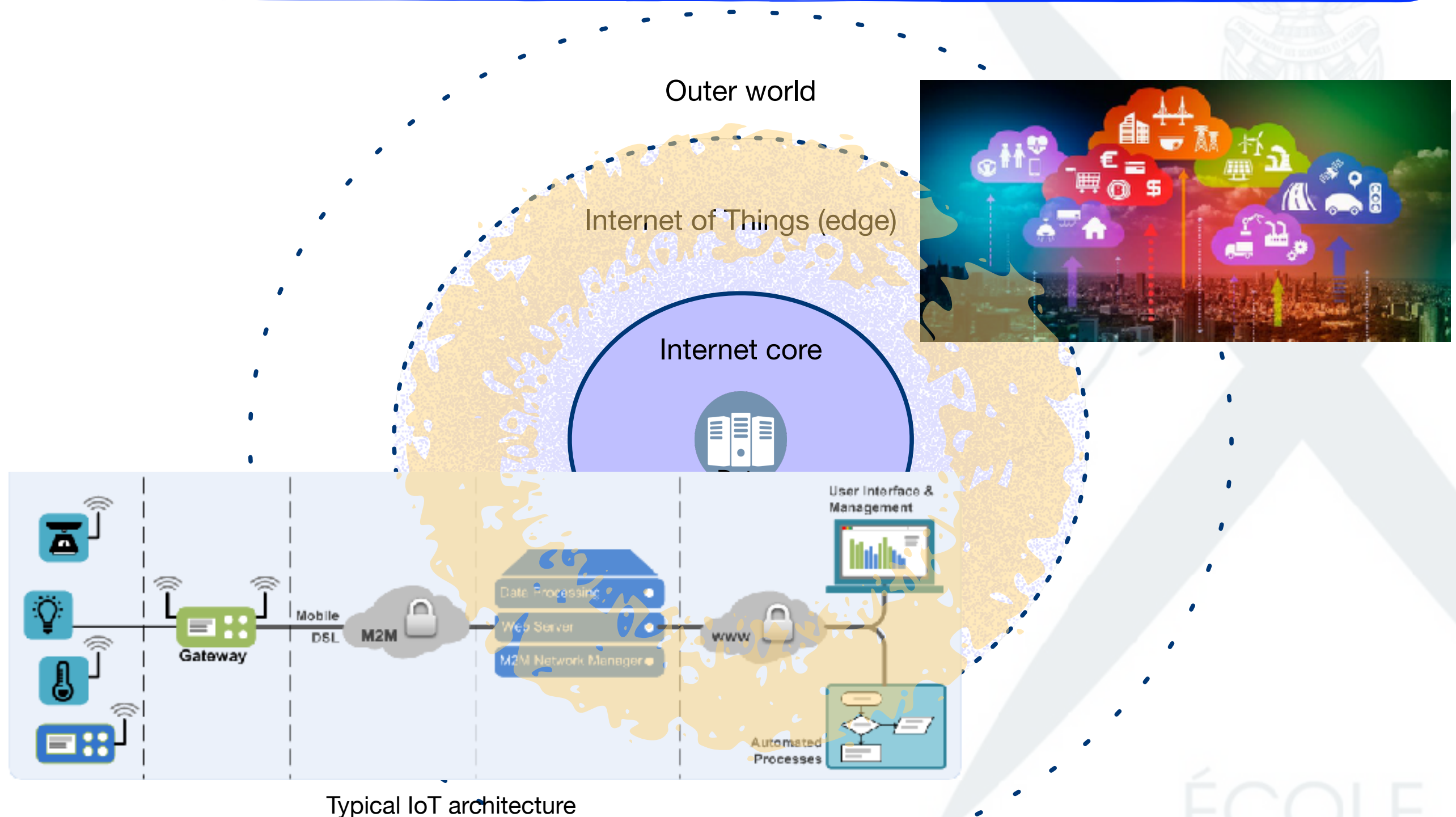
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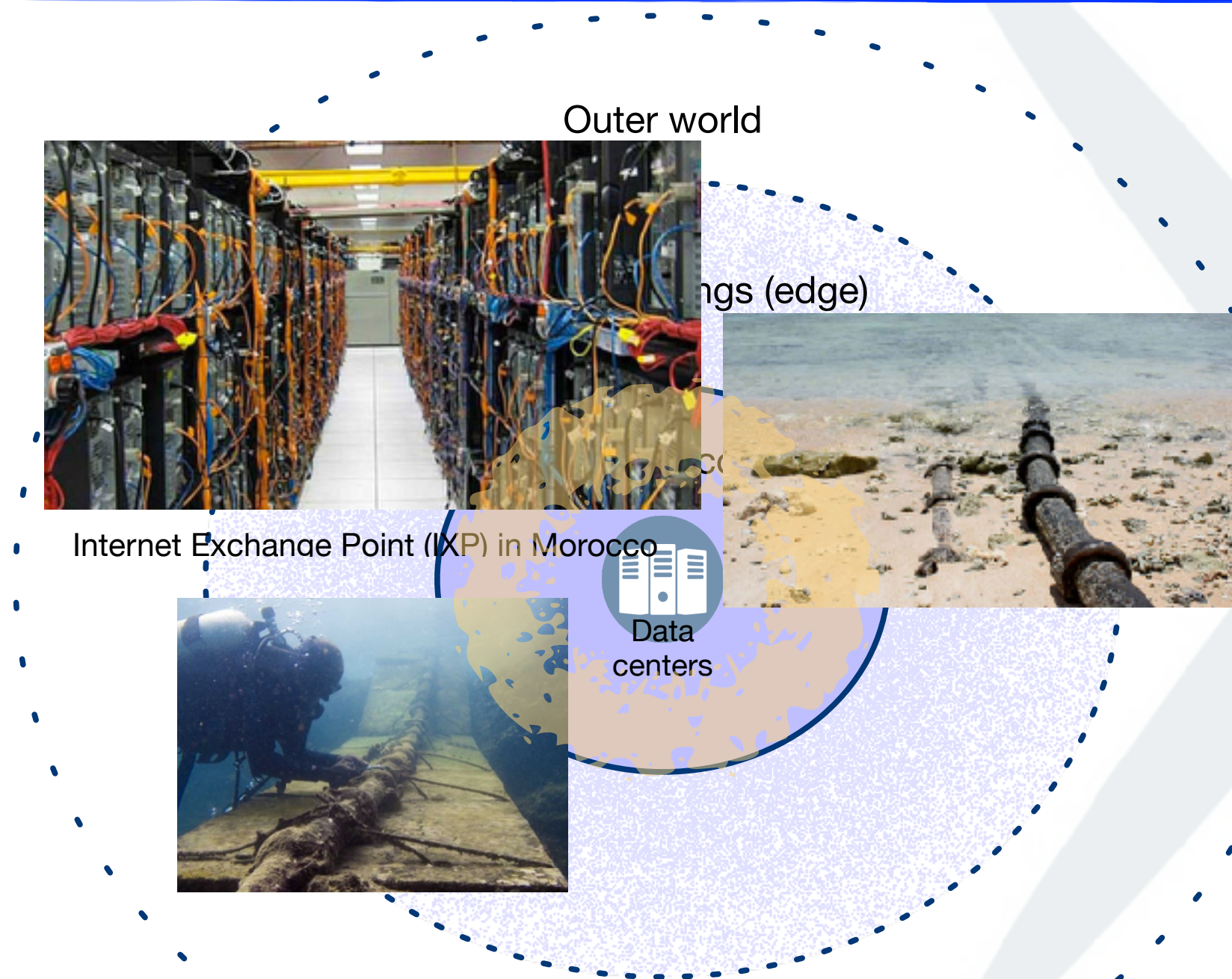
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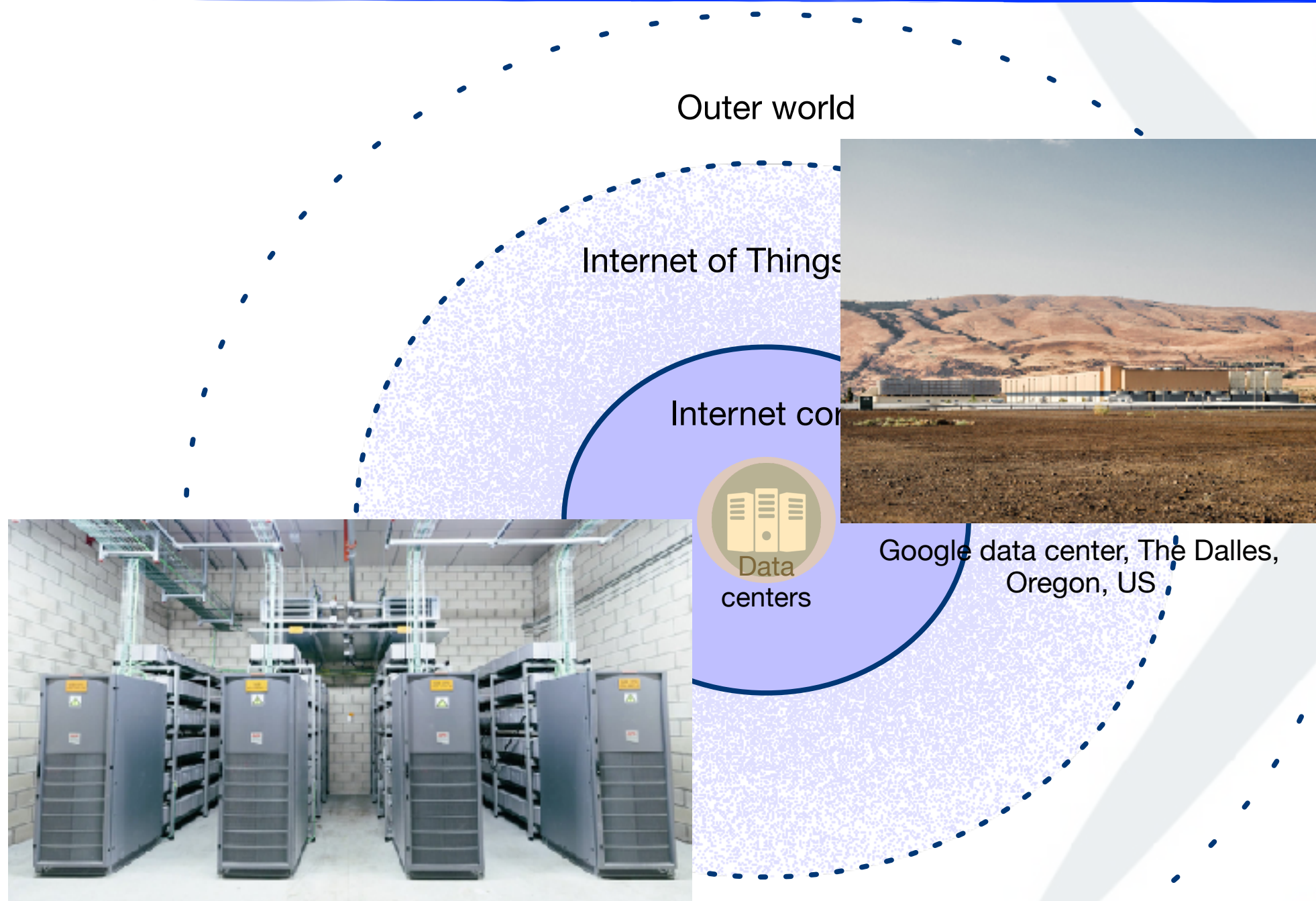
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What is “intelligence” ?

- *Philosophical / psychological open question*
- Ability to **remember** ? *memory, data collection, storage, mining, access*
- Ability to **perceive** the environment ? *sensors*
- Ability to **adapt** to the environment ? *adaptive systems*
- Ability to **learn** ? *learning systems*
- Ability to **solve** problems ? *expert systems*
- Ability to **reason** ? *automated theorem provers*



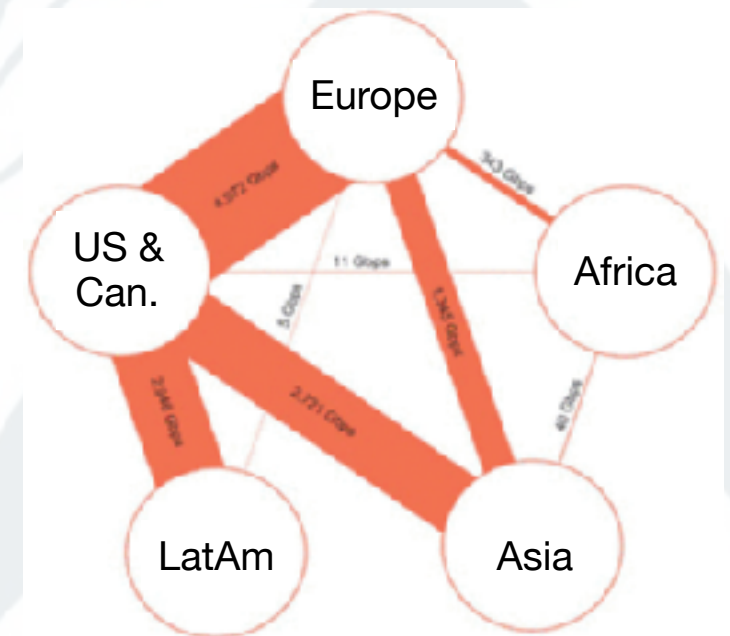
Implications : intelligent connected systems

- Intelligent **connected** systems :
intelligent (mostly) *because* connected

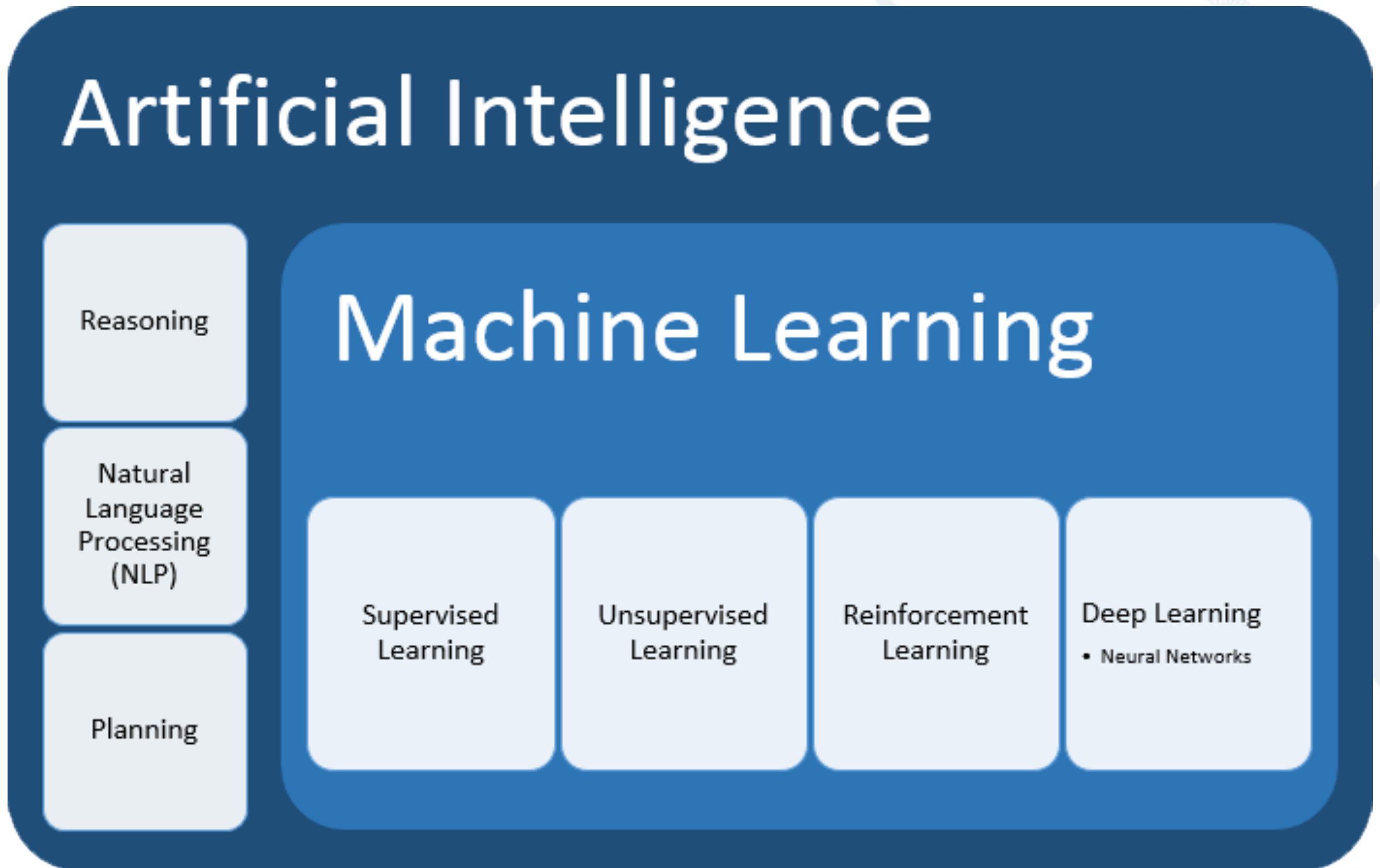
Data aggregation

Distributed vs
centralized systems

- *trade-off* between centralization and distribution
- *single vs multiple points of failure*
- *local optimization \neq global optimization*
- *complex **interaction** of different intelligent systems
(Internet, autonomous vehicles)*
 - *stability, predictability, oscillations, troubleshooting*



Intl Internet Regional Capacity (2011),
src: Telegeography Research



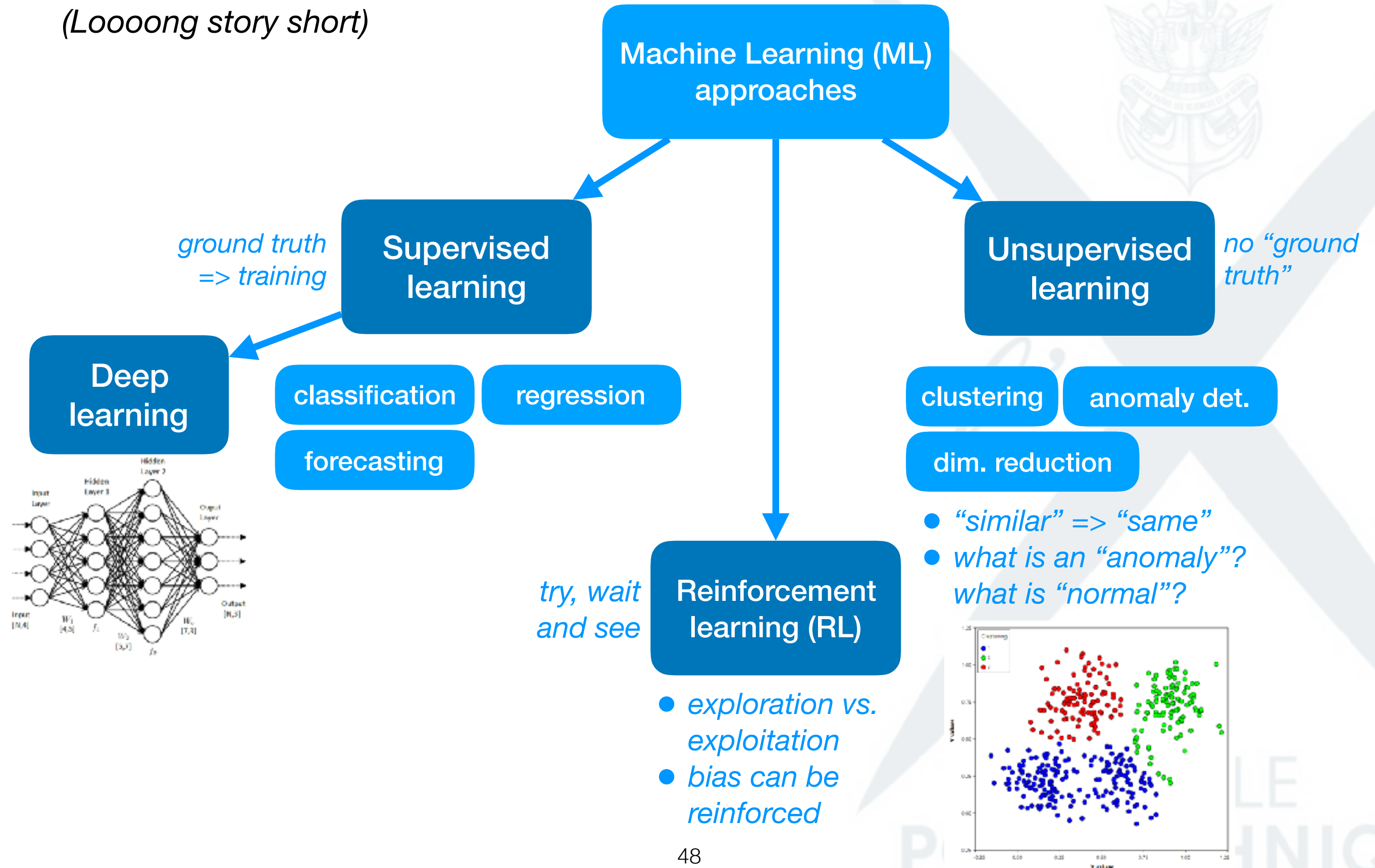


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How do machines learn ?

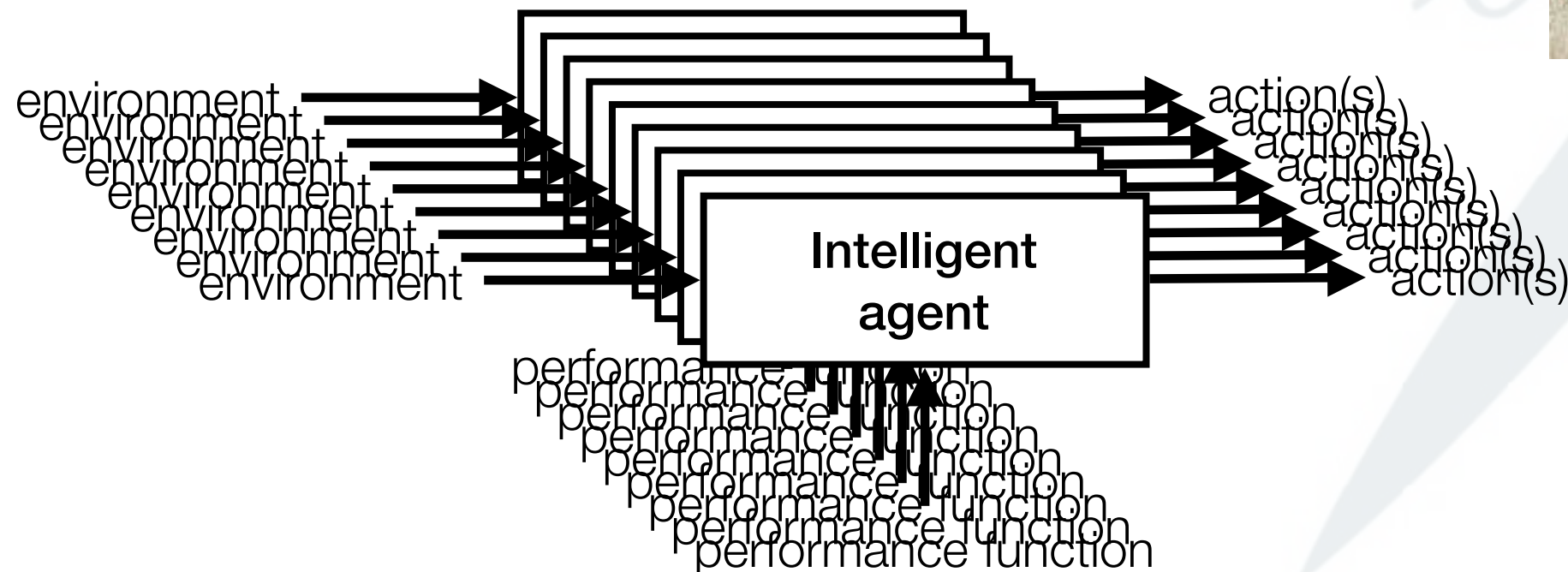
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Intelligence *et caetera*

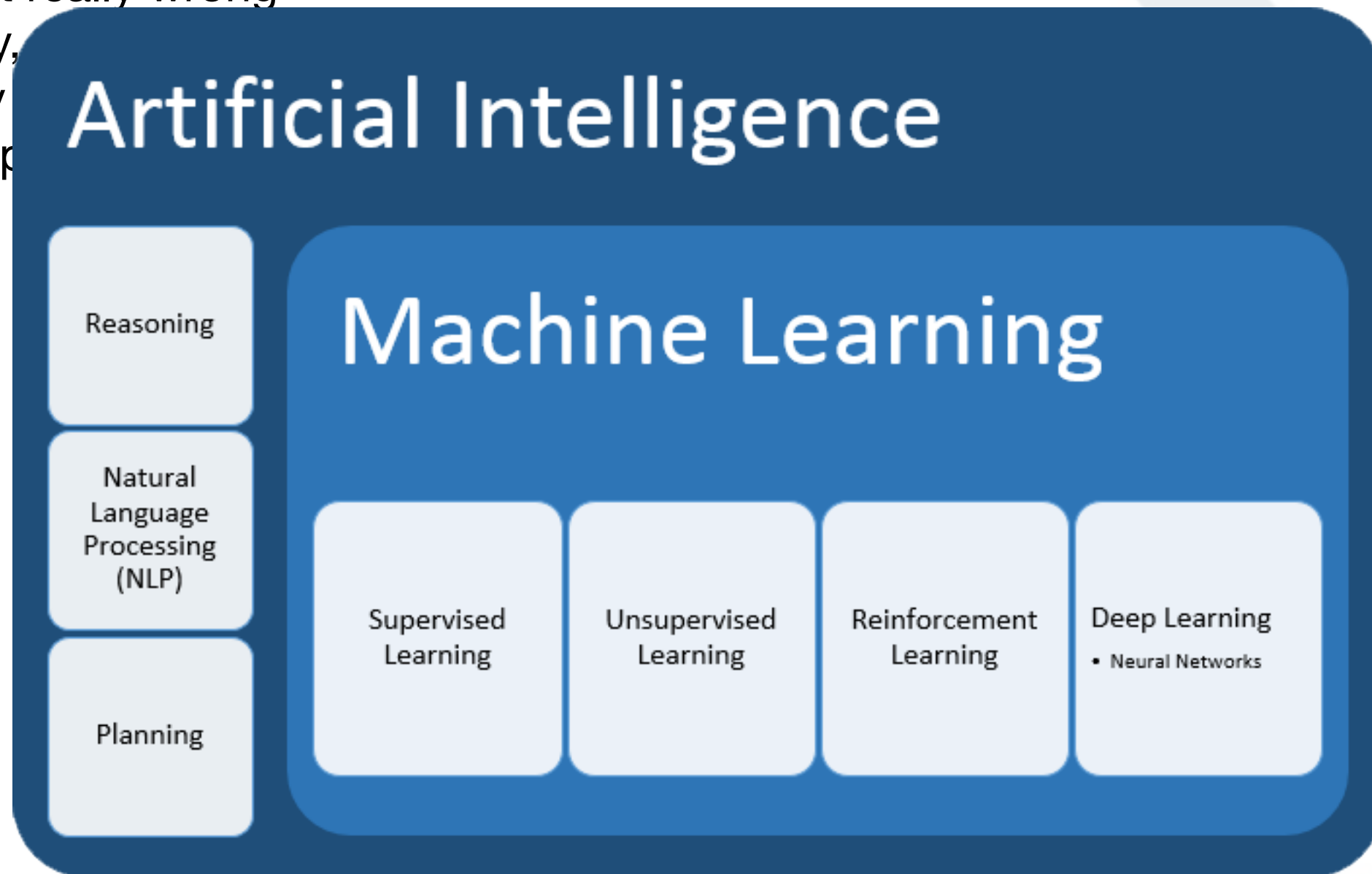
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Take-aways

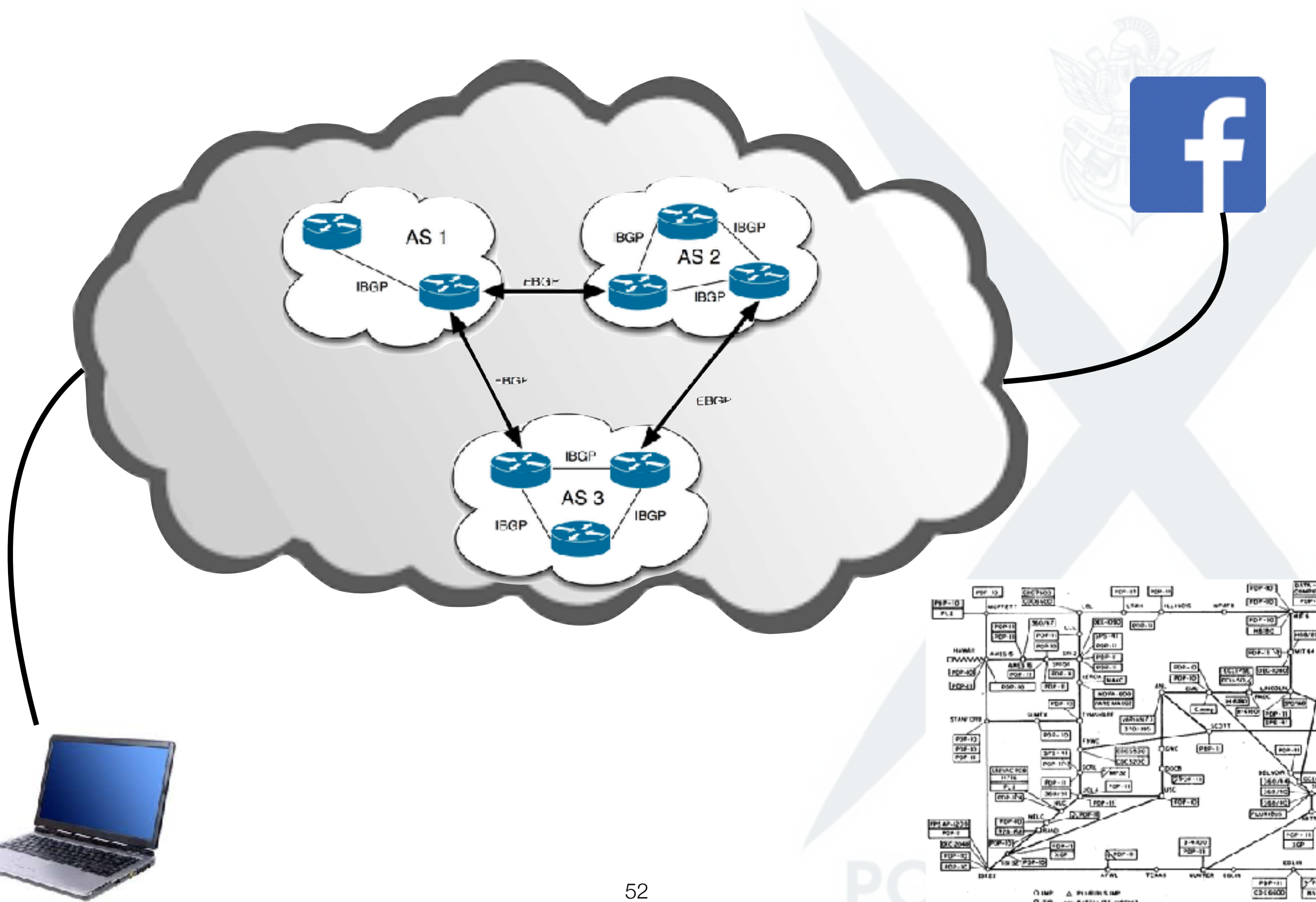
- Technology supporting critical infrastructures needs to be “minimally understood” by public
 - Not doing a great job on that extent so far
 - Example: electoral system
- Market is heavily short-sighted about risks: security, etc... only taken care of _after_ things get really wrong
 - Security,
- Centrality
 - Data is p



- Most urgent challenges derived from AI emergence don't necessarily come from where we may expect
- Intelligent systems are already part of our daily life
- Intelligent agents model: "Intelligence" is mostly limited to observation from / adaptation to the environment
 - Undesirable outcomes if the presented environment is flawed
- Singularity
- "We don't know what is going on" ("black box" (non-linear optimization) data flows (for training, learning, monitoring, etc.) and large-scale connectivity (Internet+IOT)
- Human-provided data is key in "smart" (public) services and business models
- Enabling infrastructures & technologies have become socially critical
 - Underlying issues related to access inequality, infrastructure ownership/access innovation enabling, required qualifications to interact with the resulting world
- "Smart" systems are exposed to new vulnerabilities
 - Underlying technologies were/are not designed to be safe/secure
 - Need to integrate "graceful downgrading" in designs
 - Cybersecurity attacks

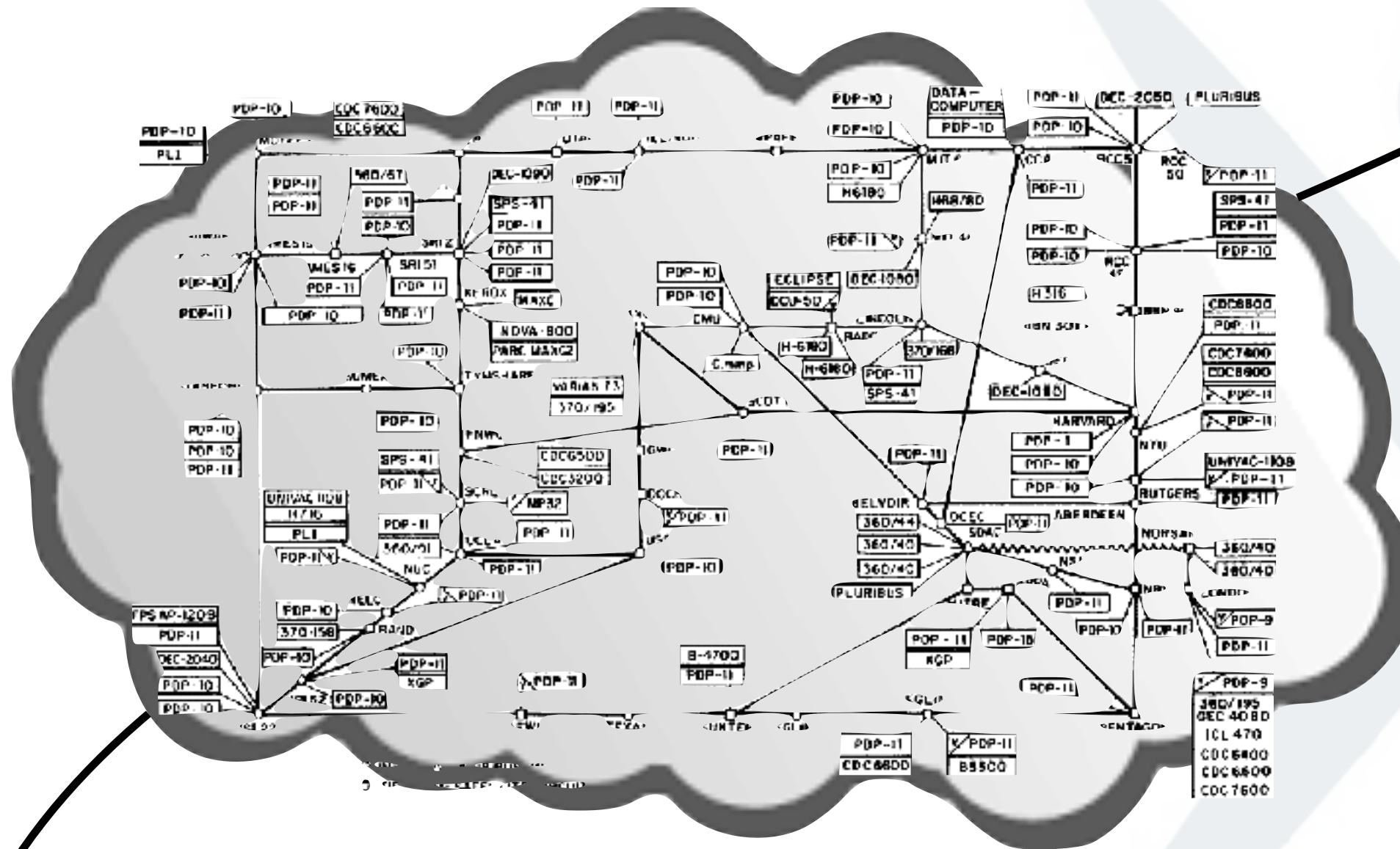


More down-to-earth “intelligent” systems



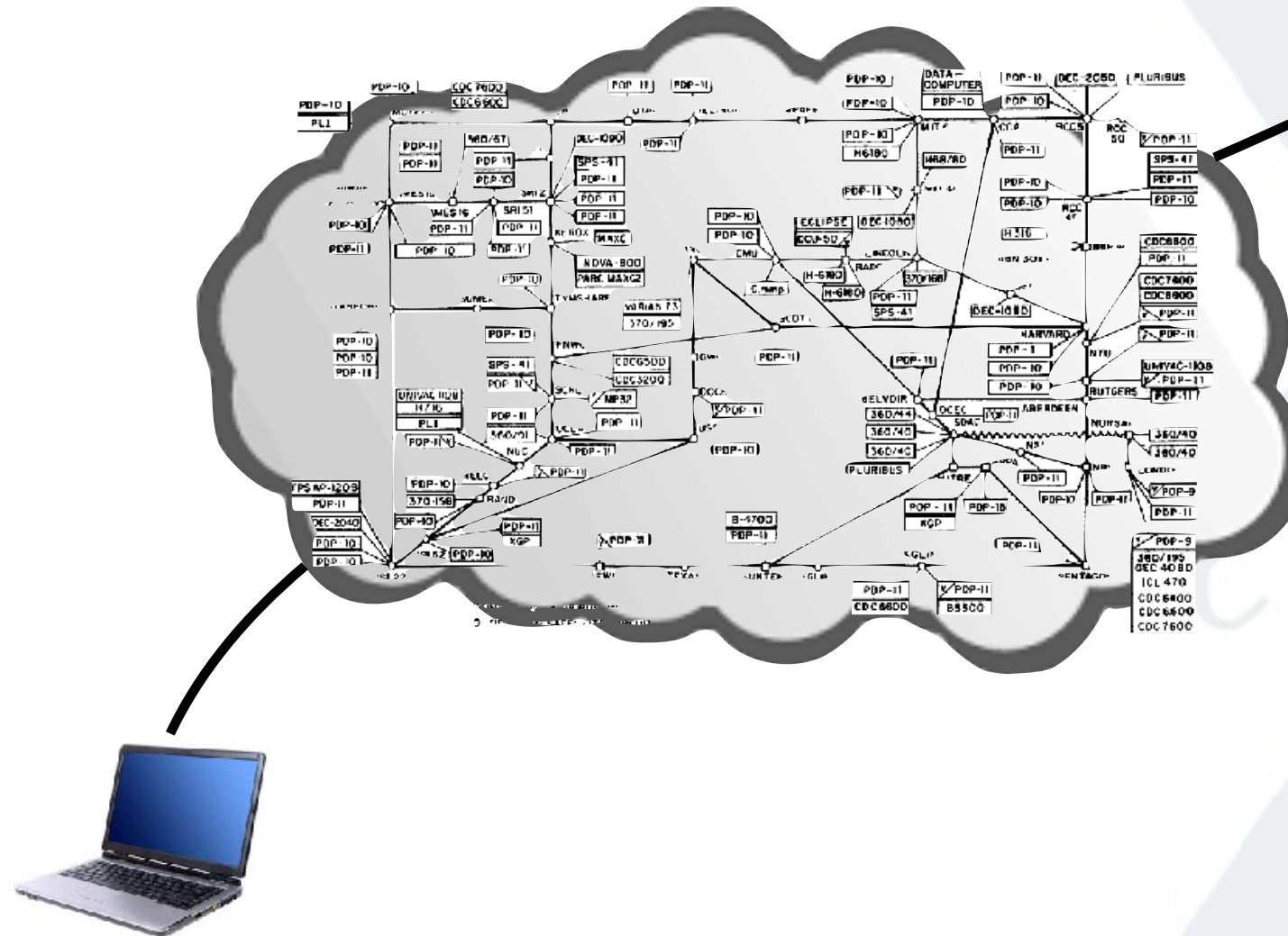
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More down-to-earth “intelligent” systems

- Distributed routing in the Internet



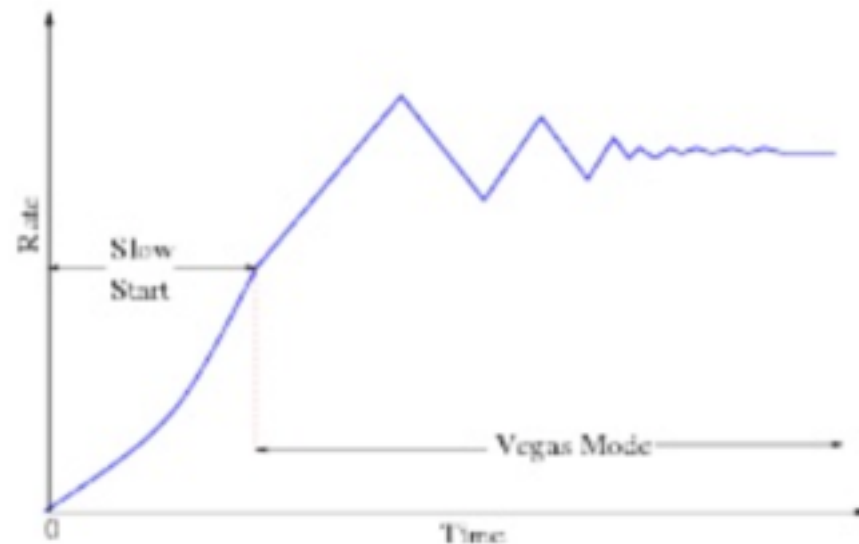
More down-to-earth “intelligent” systems

- ...or routing in the real world, with *La Poste* !



More down-to-earth “intelligent” systems

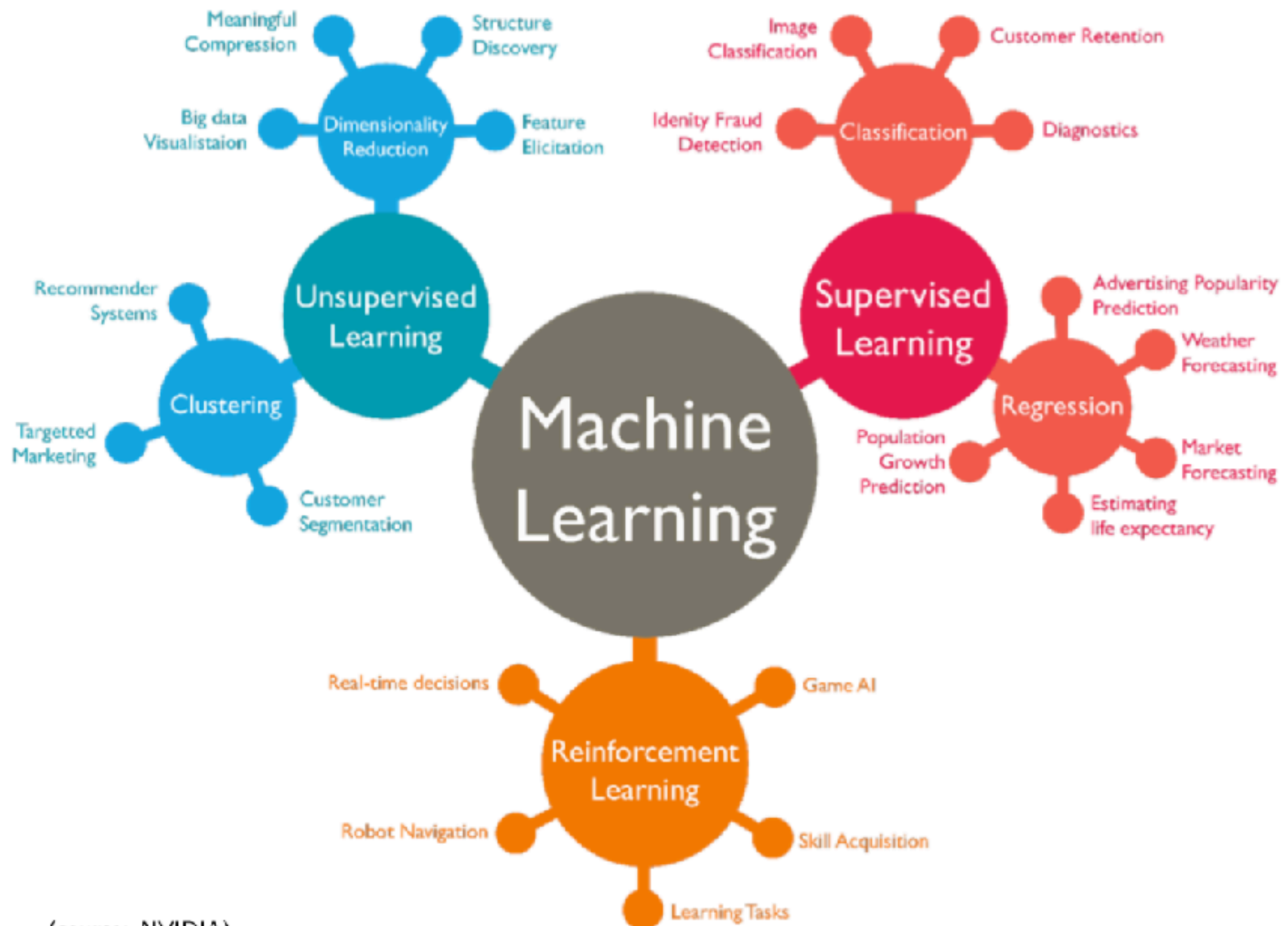
- Guessing the right data rate: congestion control in TCP



(Evolution of data rate in TCP Vegas)

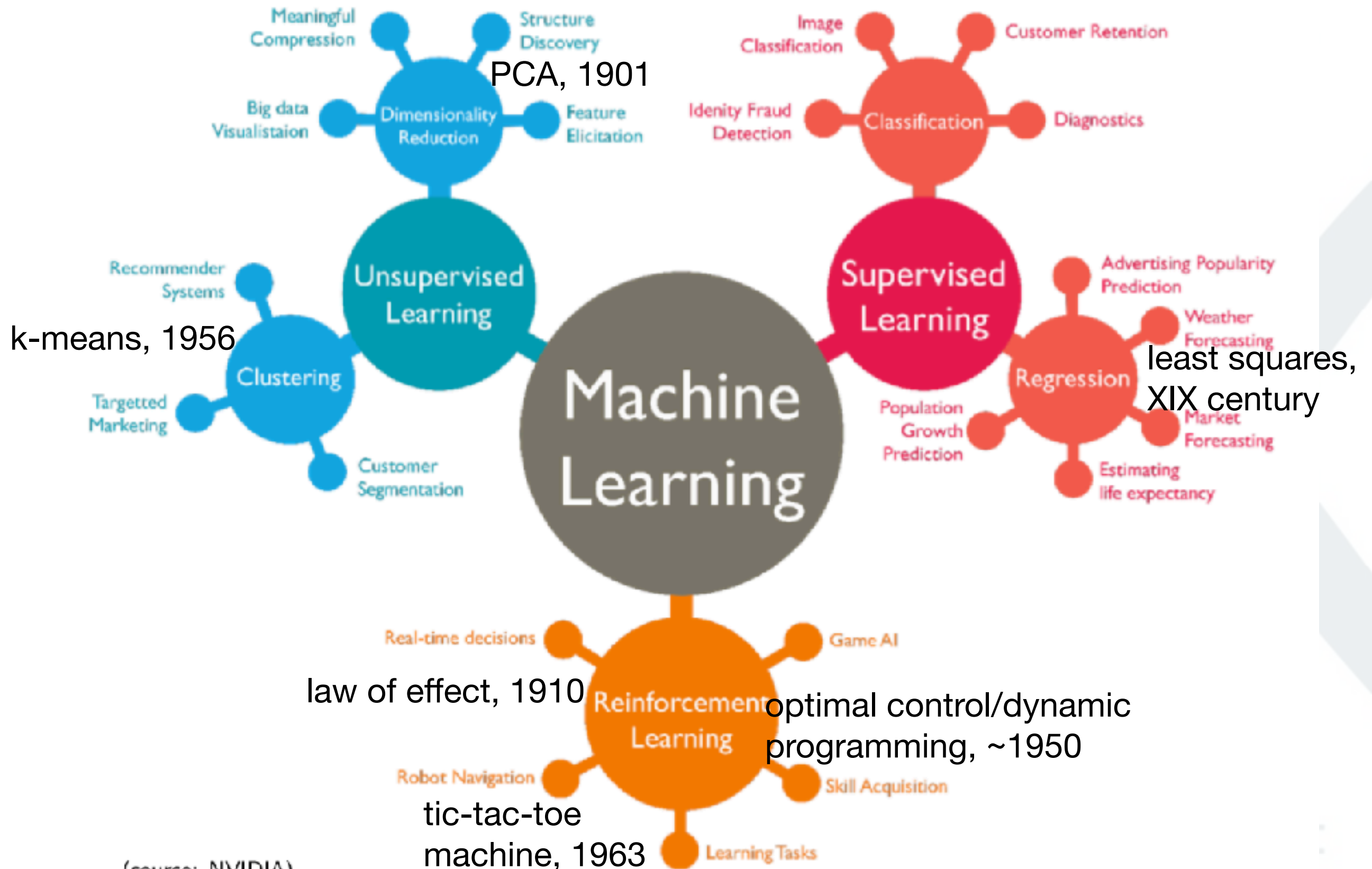
- Complex, dynamic systems
- Global outcomes depend on multiple distributed, uncoordinated decisions
- Nobody knows everything
- ...need to adapt

How machines learn



(source: NVIDIA)

How machines learn

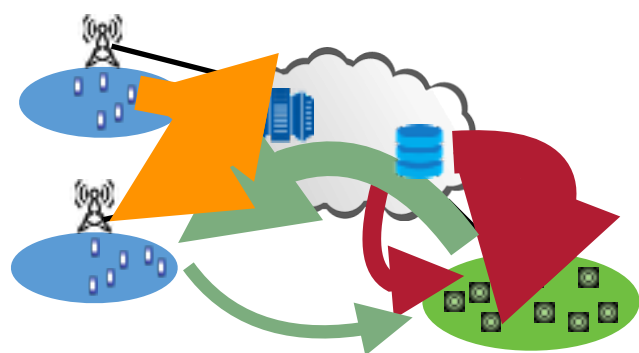
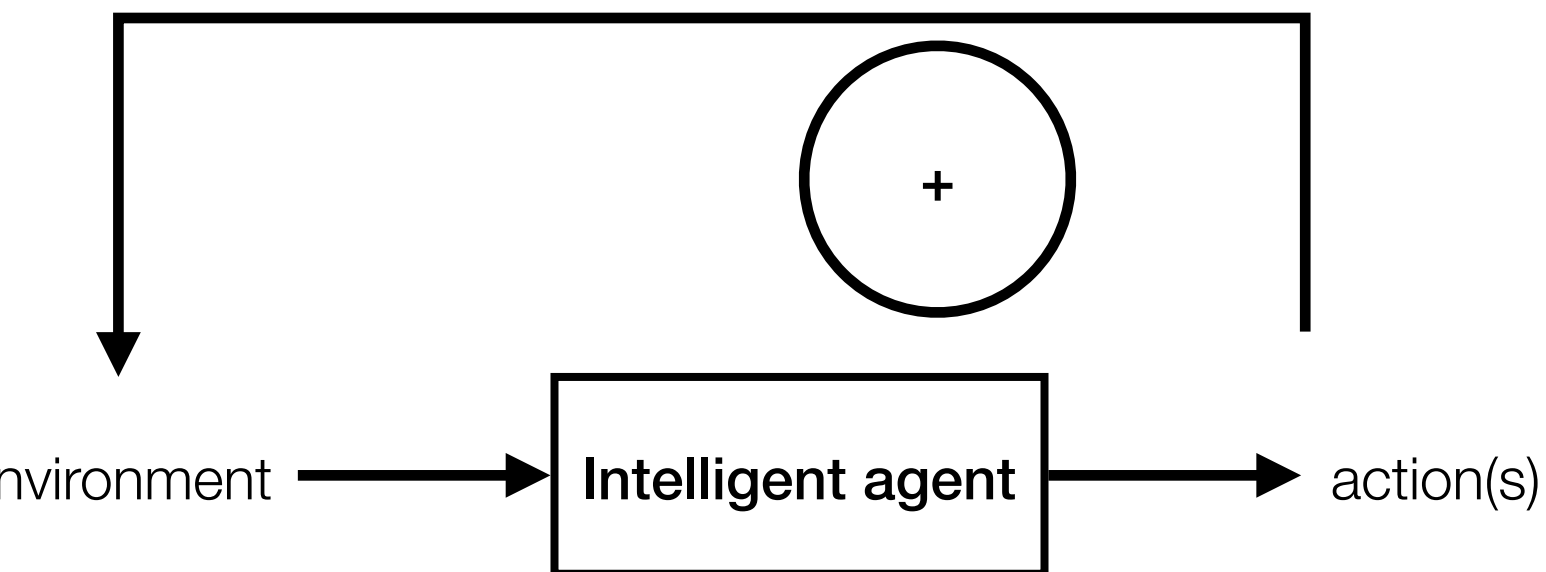


(source: NVIDIA)

Neural networks (from INF442)

- History

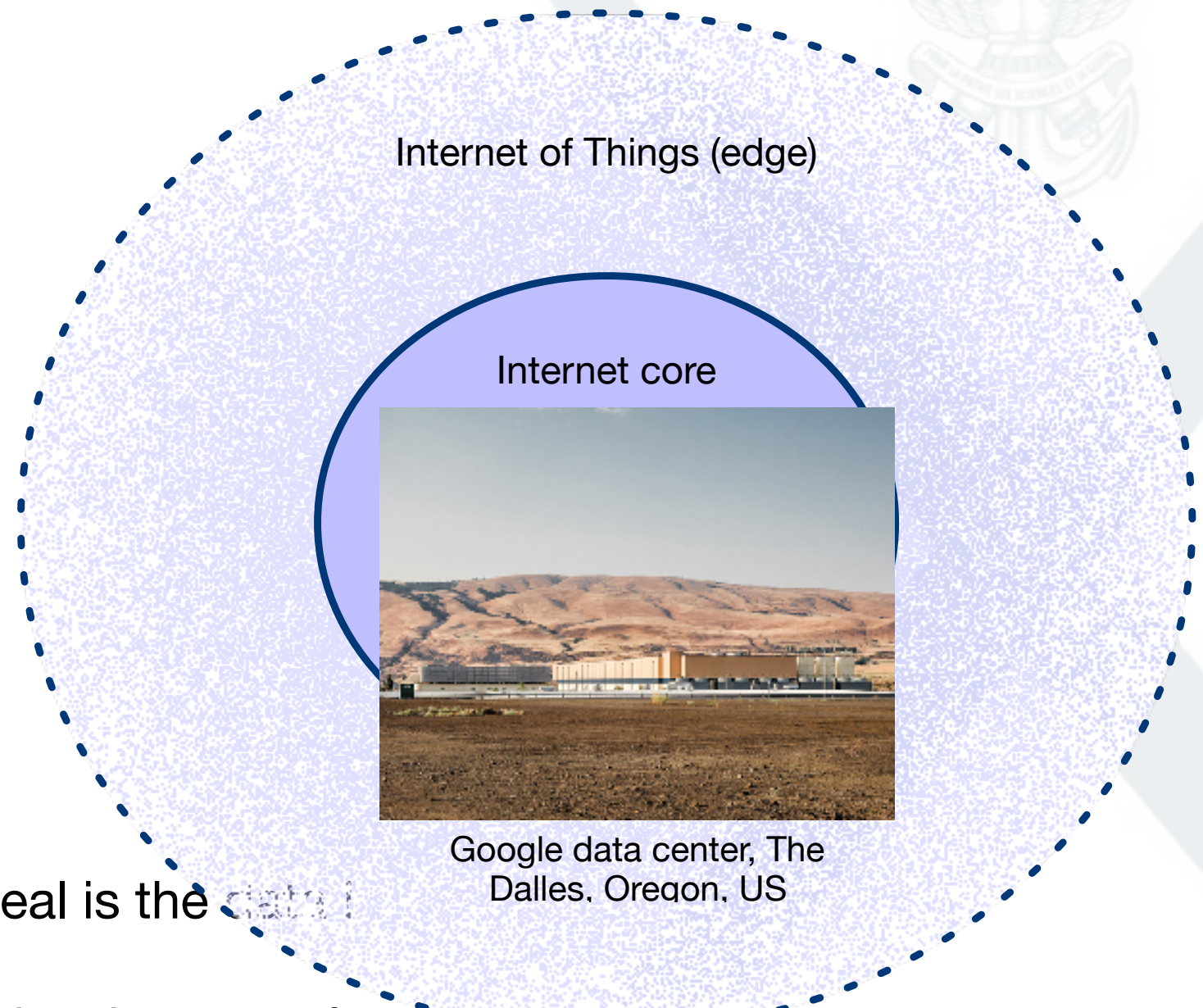
- 1943, McCulloch, Pitts: neuron model for logical gates
- 1957, Rosenblatt: perceptron for single neuron training
- 1986, Hinton: backpropagation for neural networks
- 1989, Universal approximation theorem: any function can be approximated by a neural network



What is new about all this?

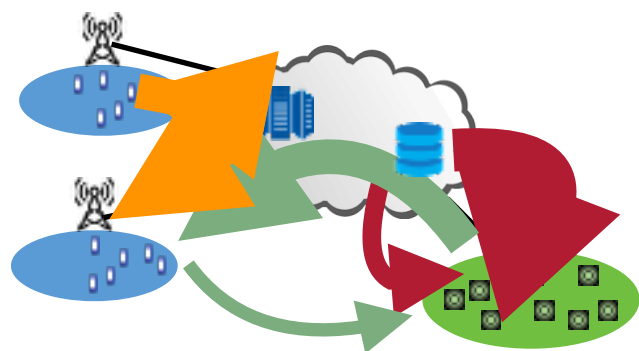
What is new is **scale**

- Big Data
- IOT
- ...Moore's law



The biggest deal is the ~~data~~ **data**!

- Data is politics: how you formalize your environment (dimensions), how you define optimization (metrics)
- Data is money: digital economy, digital business models, and “smart” public services rely on an increasing flow of data



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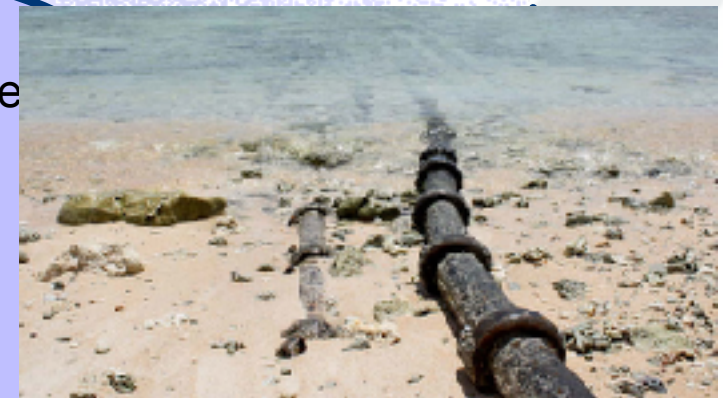
- ...Moore's law



Internet Exchange Point (IXP) in Morocco

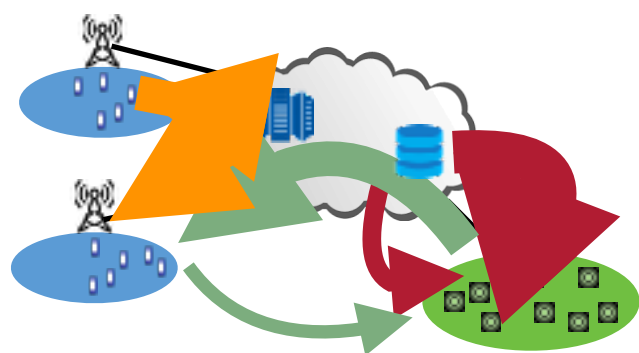
Internet of Things (edge)

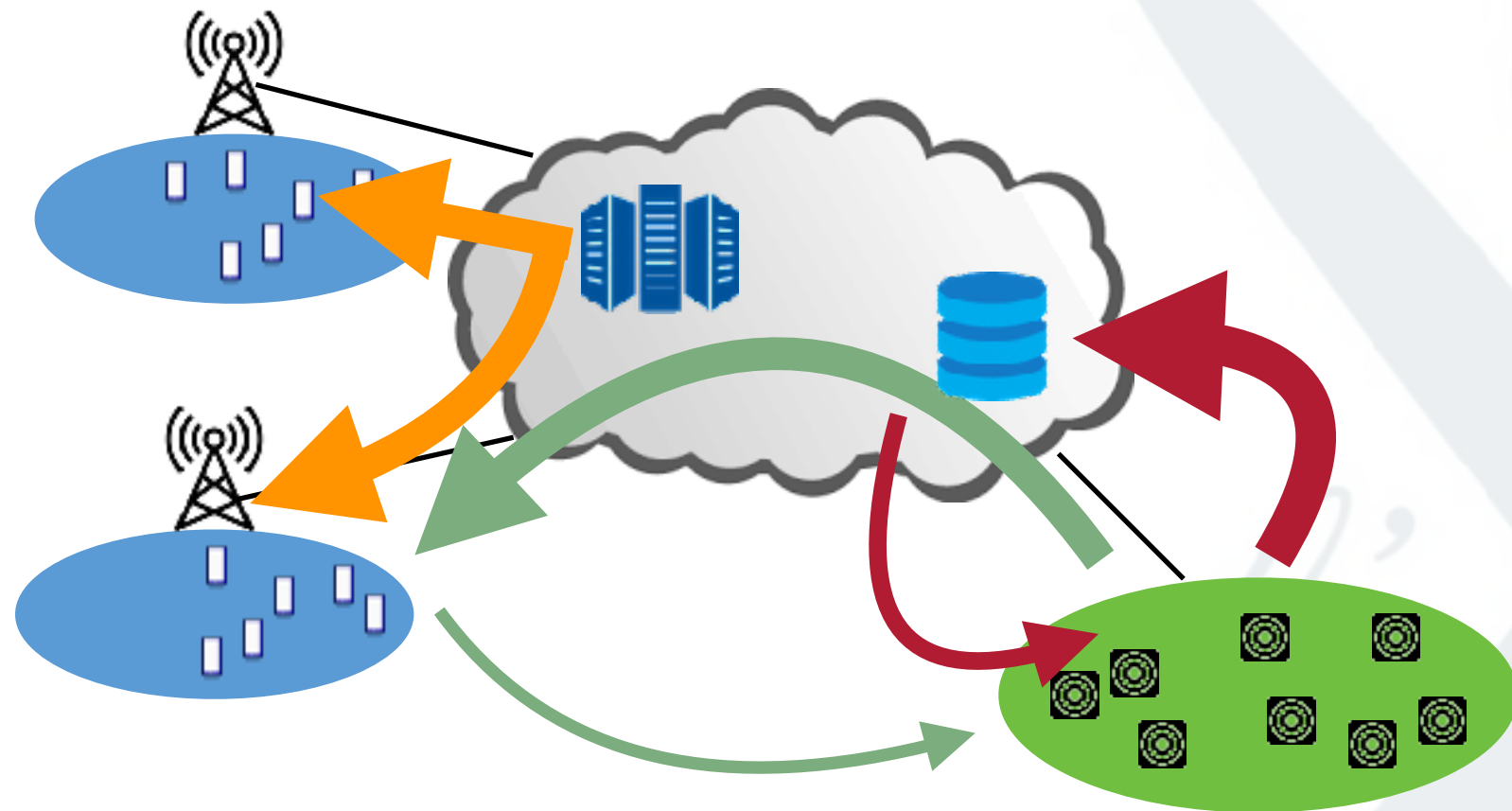
Internet core



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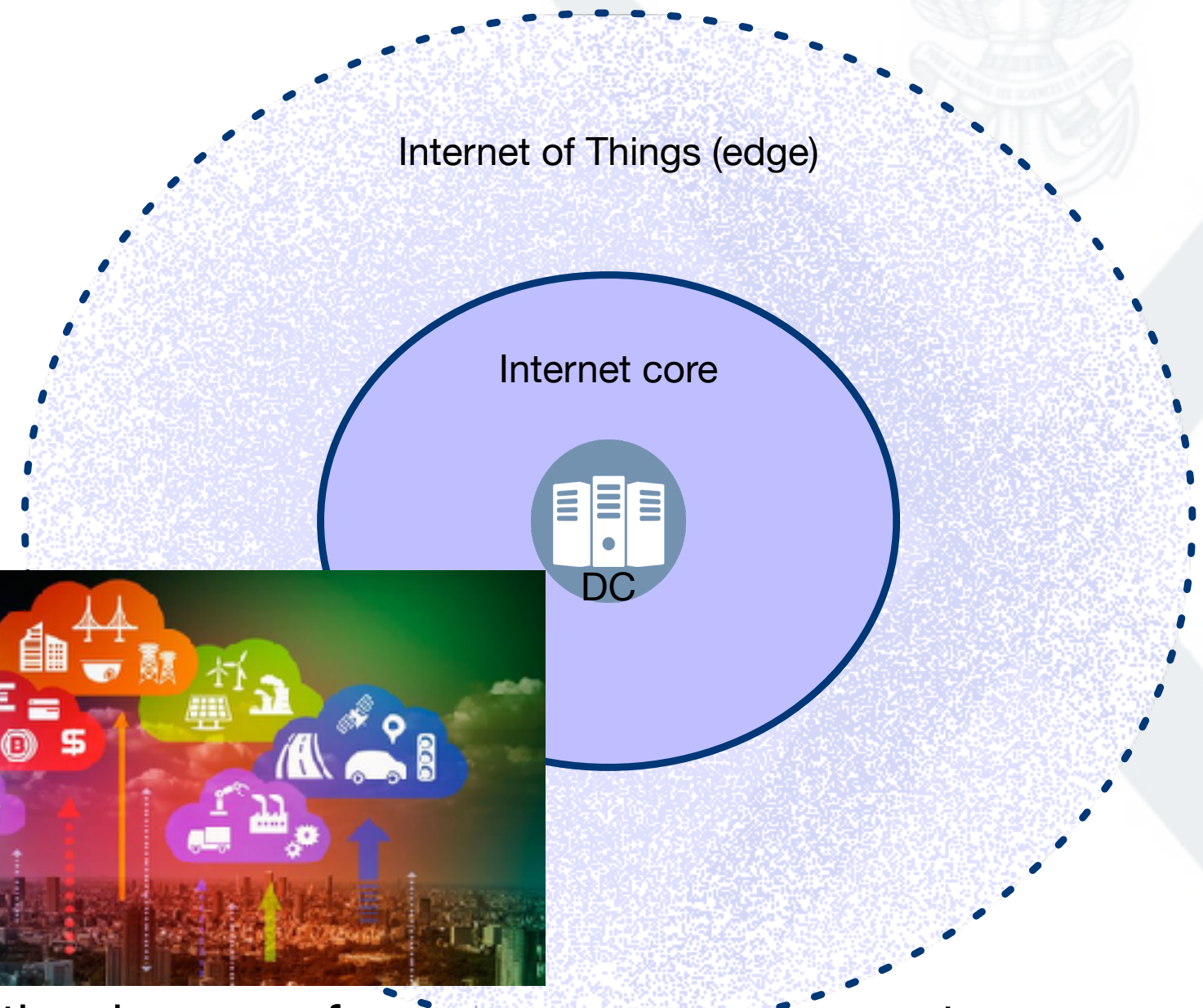




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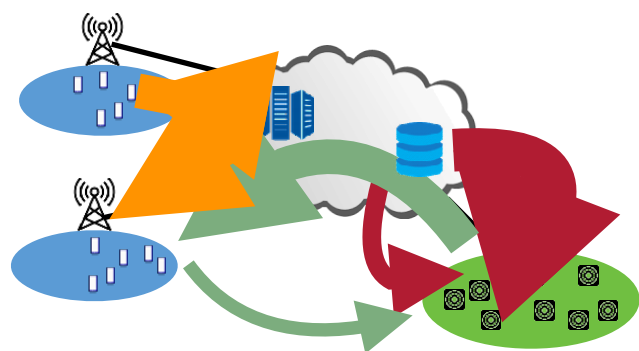
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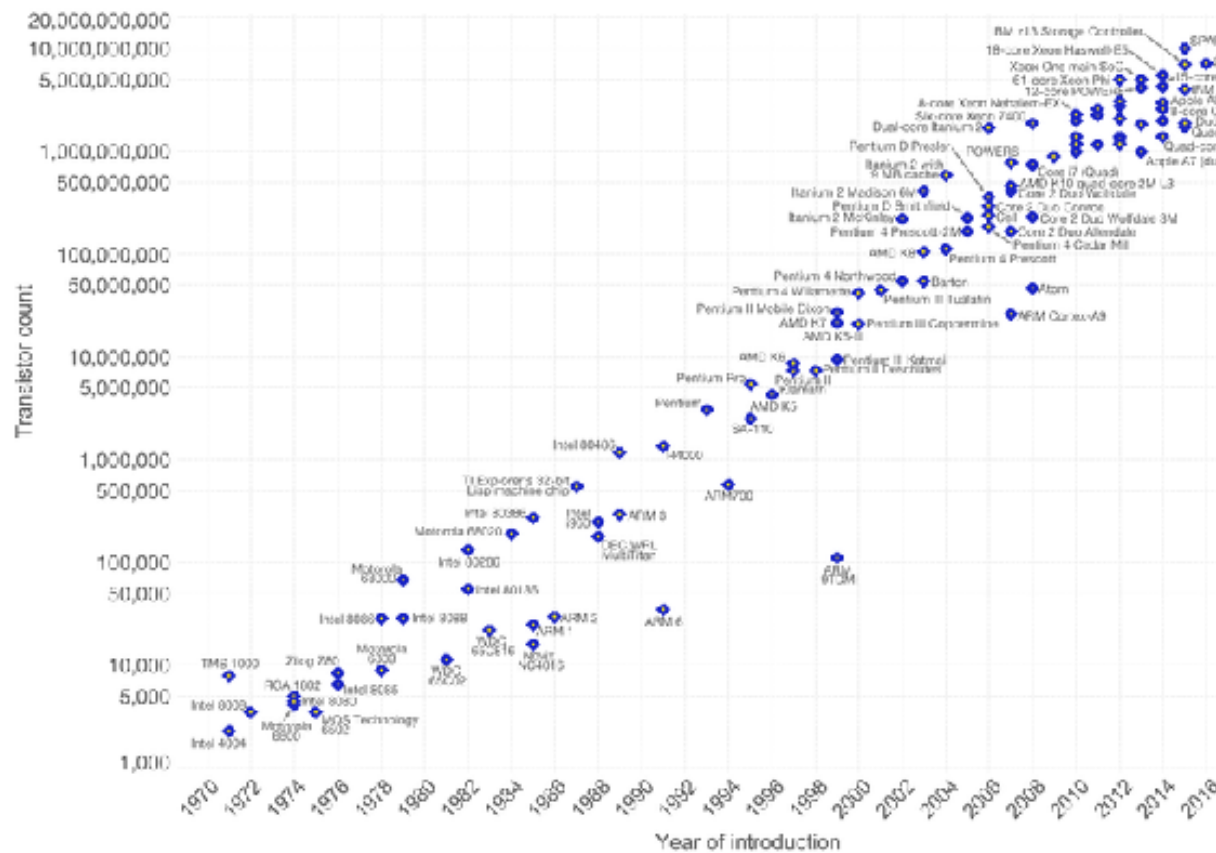


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Moore's law



Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)

The data visualization is available at [OurWorldinData.org](https://ourworldindata.org). There you find more visualizations and research on this topic.

Licensed under [CC-BY-SA](#) by the author Max Roser

Slightly different flavours, but same message:

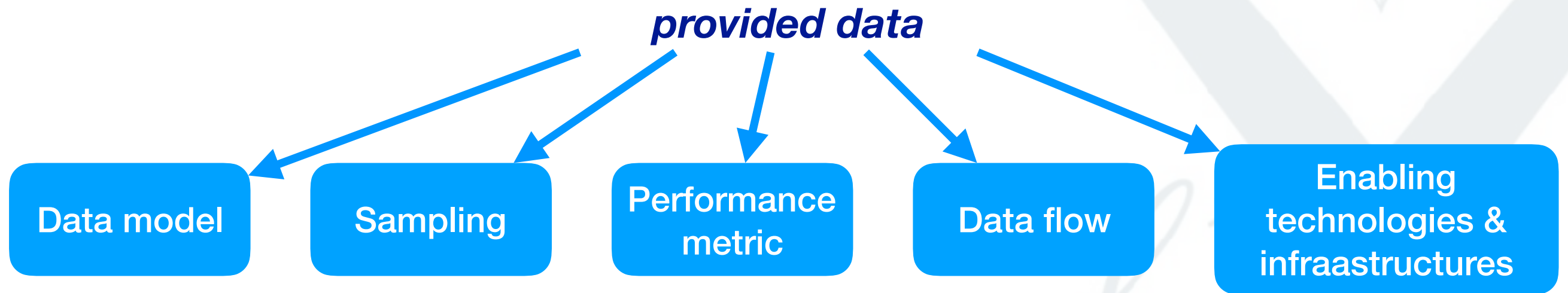
*“computing capacity (or # transistors per IC) **duplicates** roughly **every 2 years**”*

- Other ex.: price of electronic products, processing speed of μ processors
- Empirical observation

What is new about all this?

*What is new is the **scale***

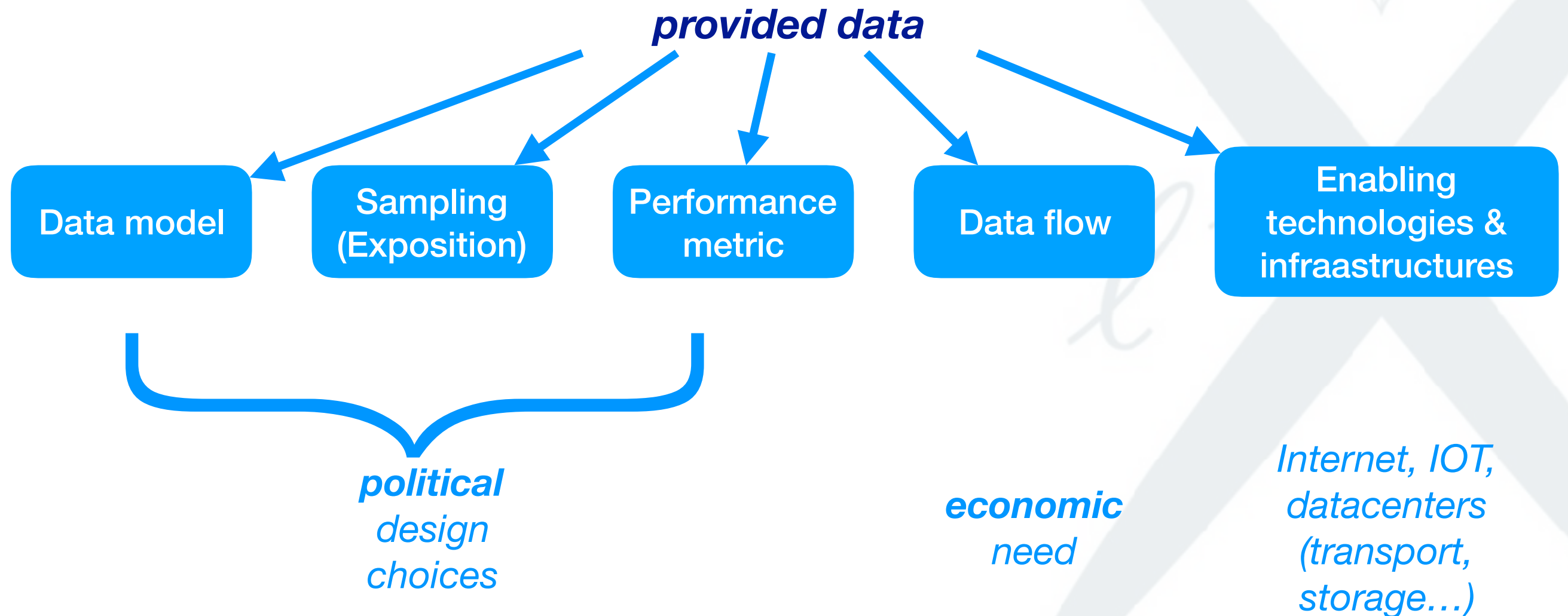
Intelligent systems heavily depend on



What is new about all this?

What is new is the scale

Intelligent systems heavily depend on



What happened in previous technological revolutions?

- Printer
- Electricity
- Car



Implications for smart cities, public services and critical infrastructures

- Data centrality
 - Who defines model, sampling, performance metrics?
 - Public disclosure
 - Data management: privacy, ownership
- Enabling technologies become critical
 - Networking infrastructures, hardware, protocols
 - Net neutrality
 - Access inequalities (e.g. 5G)
- Vulnerabilities, sensibility to crashes
 - Security, safety
 - Centralized vs distributed
 - Simple point of failure vs local recovery capacity
 - “It’s smart to play dumb”: downgrading gracefully
- “Understandability” of involved systems
 - You fear what you don’t understand
- Augmentation vs substitution
 - Actual responsibility on system’s outcomes

Implications for smart cities, public services and critical infrastructures

1. Intelligence needs data:

1. (Economics)
2. are we willing to give it? (is privacy an European-Western concern?)
3. shouldn't we get paid for it? (data-based income)
4. Data management: privacy, ownership

• Progress of networked- and intelligent-systems turn the world (cities, public services, etc.) dependent of a few “enabling technologies”. Enabling technologies become critical

- ...this has happened before
- Networking infrastructures, hardware, protocols
- Net neutrality and common carriers
- Access inequalities (e.g. 5G)
- What if these technologies are not available? Are we able to downgrade gracefully?
 5. ...but, we didn't do very well on previous enabling technologies (societies vulnerable to attacks, electricity shutdowns, transport blocking, water poisoning...)

• Vulnerabilities, sensibility to crashes

- Security, safety

2. Fundamental trade-off between centralized/distributed decisions in collective systems (e.g. smart cities, smart grid)

1. Distributed intelligence: aggregation of “individual” (automated) decisions: local optima do not always lead to global optima!
2. Stability, etc.

1. World (cities etc.): dependent of new “enabling technologies”

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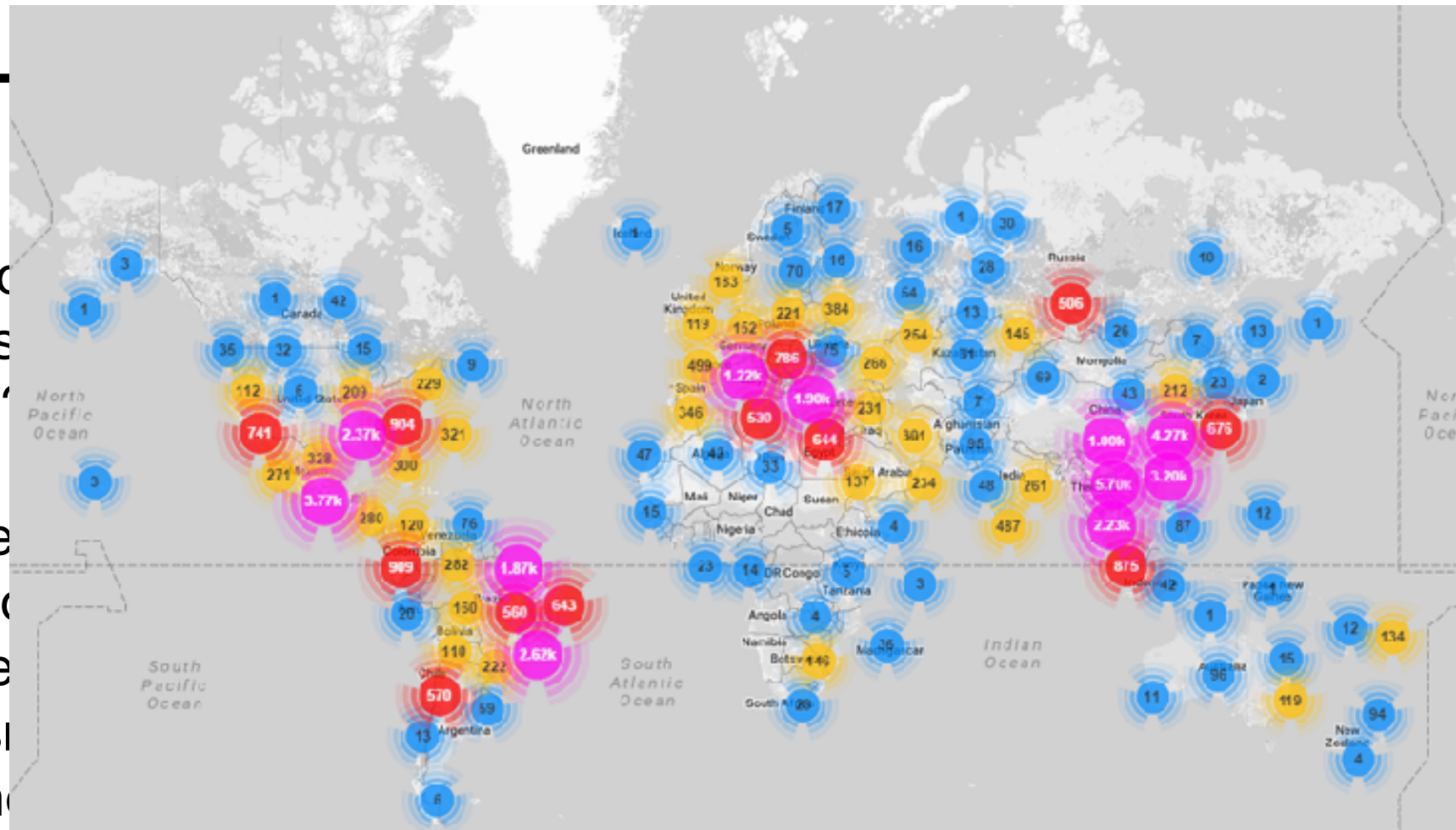
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Your smart home is only as smart as the network that runs it.

On Sunday, some Google users found themselves locked out of YouTube and Gmail as the tech giant experienced major outages across the U.S. But the service disruption only affected most users' browsing history, other than their homes malfunction. Nest, a Google-owned smart home company,

Going further: augmentation or substitution?

- TBD

1. Lots of things that “do not deserve our attention” will happen automatically
 1. what things?
 2. which are the high-level objectives? how do we measure them?
 3. are we fine with the default outcome?

Looking ahead

1. Hype of AI/learning
 1. Remarkable milestones (and some terrifying cases...)
2. But, automated learning/reasoning is already part of our world (...depuis longtemps)
 1. In my field: routing, La Poste, TCP Vegas (TCP is 40yo): are these “intelligent systems”?
3. What is intelligence?
 1. Definitions
 2. Is really new? (antecessors of AI/learning)
4. Since it's not new... What changes?
 1. Big Data: huge amounts of data
 2. IOT: ability to collect
 3. (both made possible by Moore's law)
5. What happened in previous technological revolutions?
 1. “La ciudad automática”, introduction of electricity, public transport
6. Implications
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Implications : intelligent connected systems

- Intelligent **connected** systems :
intelligent (mostly) **because** connected

Data aggregation

Distributed vs
centralized systems

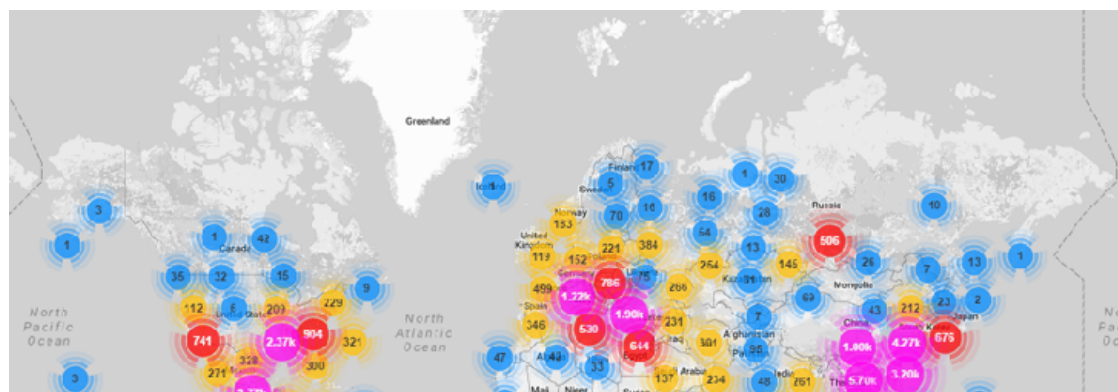
Enabling
technologies &
infrastructures

*Internet, IOT,
datacenters
(transport,
storage...)*

*what if not
available?
“graceful
downgrade”*

*Internet: not conceived to become this big
(=> insecure)*

*IOT systems are not typically designed with
security in mind*

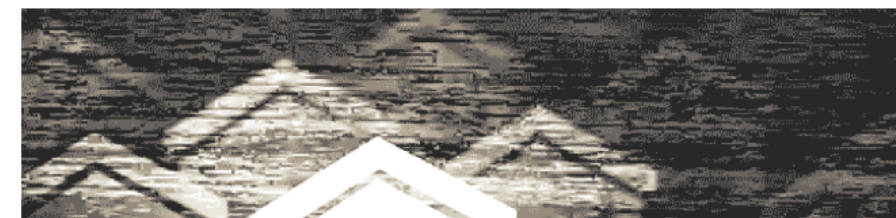


BRAAAINS cybersecurity risks How Google City Skyline Turns Smart Homes Into Zombies

Users reported doors, baby monitors, and thermostats going kaput. The Internet of Things is convenient—until there's no Internet.

Kelly Weill
Reporter

Updated 06.03.19 4:37PM ET / Published 06.03.19 2:56PM ET



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Data aggregation

economic
need

- Vulnerabilities, sensibility to crashes

- Security, safety
- Centralized vs distributed

- Simple point of failure vs local recovery capacity

- “It’s smart to play dumb”: downgrading gracefully

- *trade-off between centralization and distribution*

- *single vs multiple points of failure*

- *local optimization != global optimization*

- *“graceful downgrade”*

- *what if not available?*

- *“graceful downgrade”*

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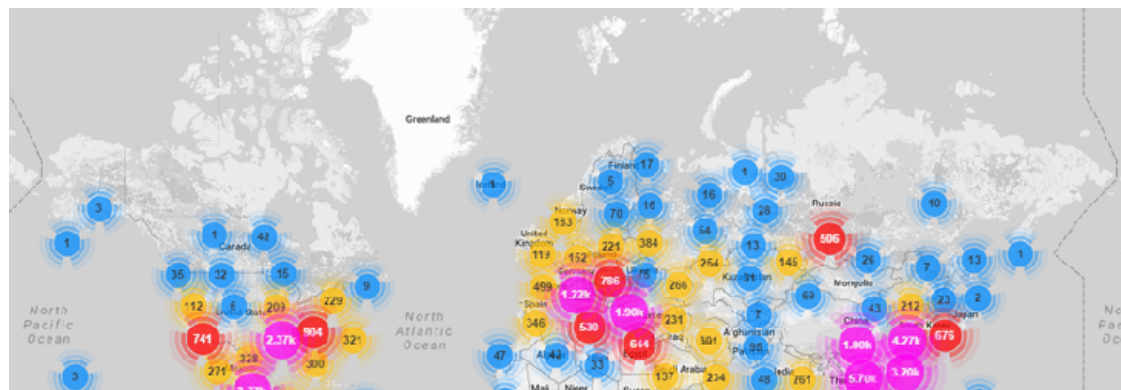
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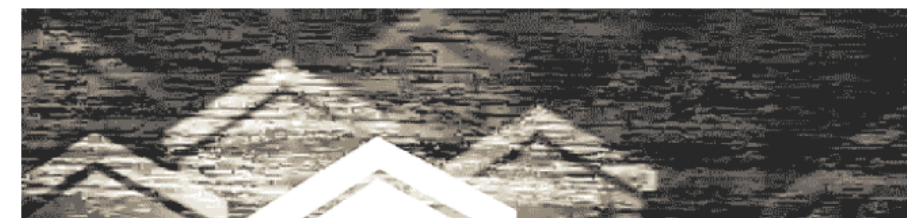


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Distributed vs centralized systems

Enabling technologies & infrastructures

Internet, IOT, datacenters (transport, storage...)

New, intelligent systems typically output dependent on

- Internet: no security (=⇒ insecurity)
- IOT systems
- Datacenters

Cybersecurity

What if not all

BRAAAINS

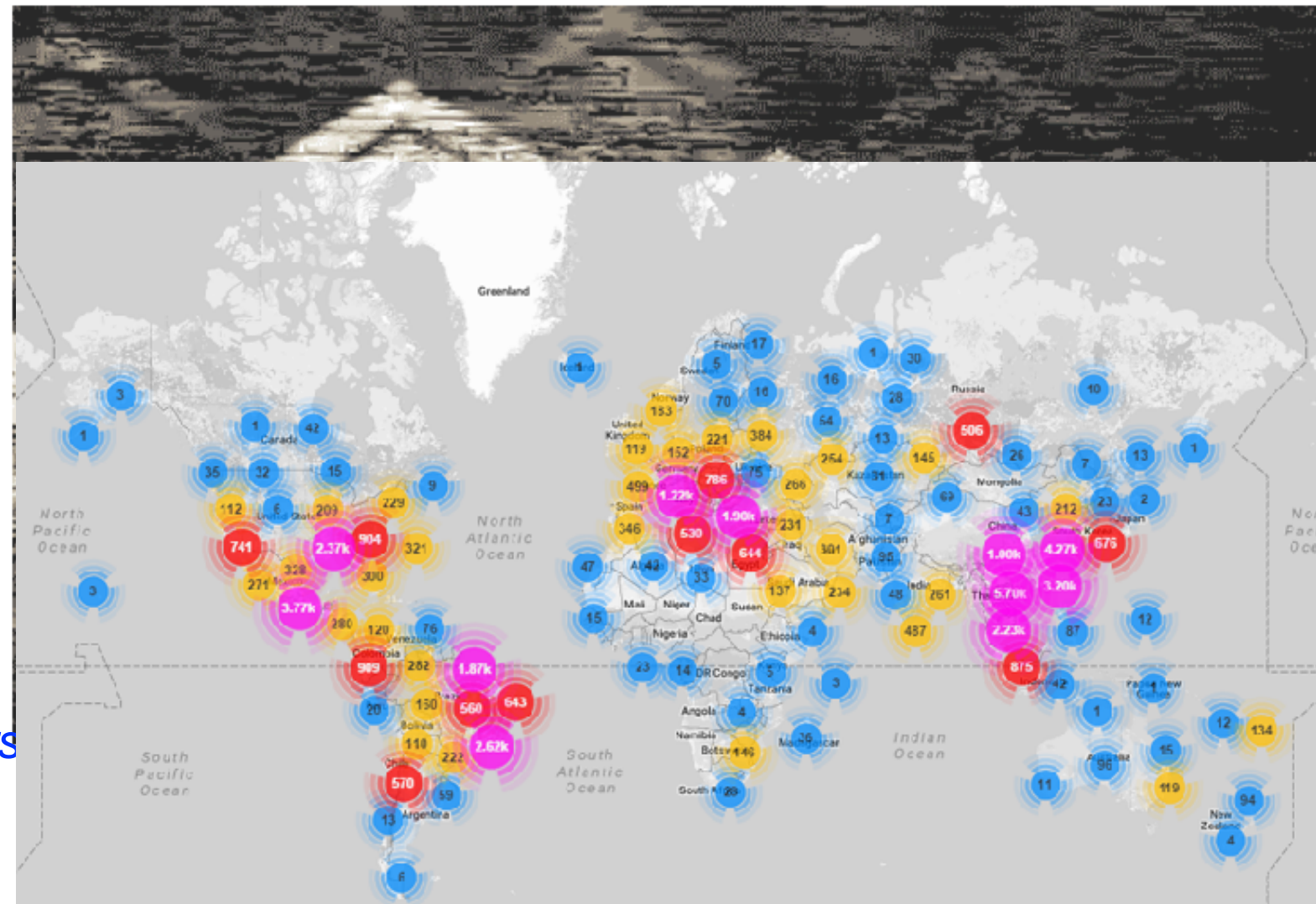
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