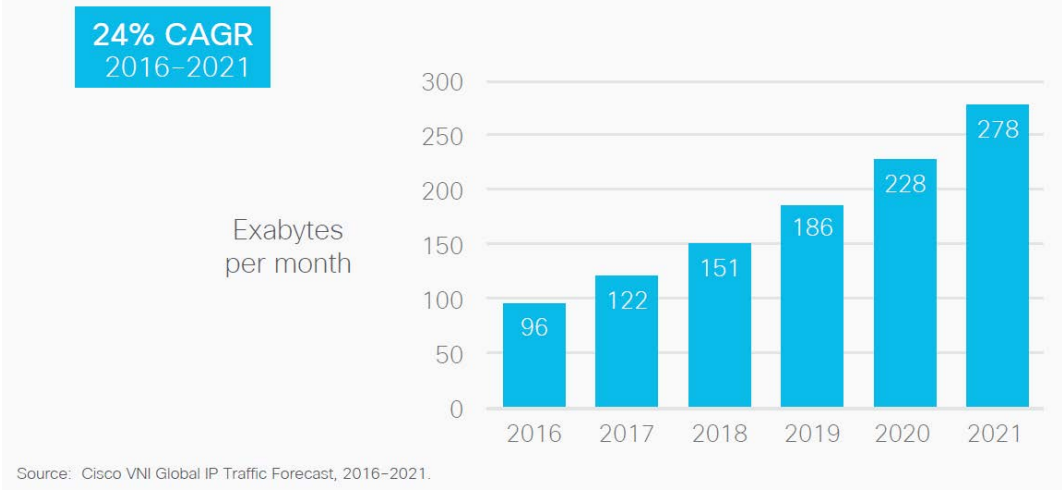
Towards a Data-Driven Society.

Challenges and research perspectives for a Next Generation Internet integrating networking, data management and computing

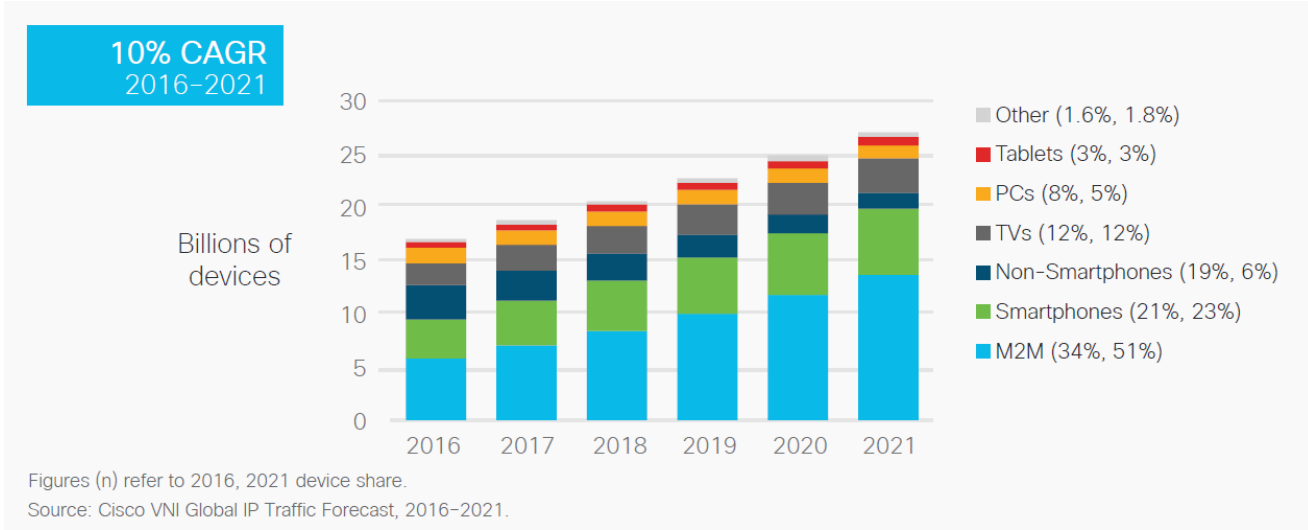
Roberto MINERVA

Outline

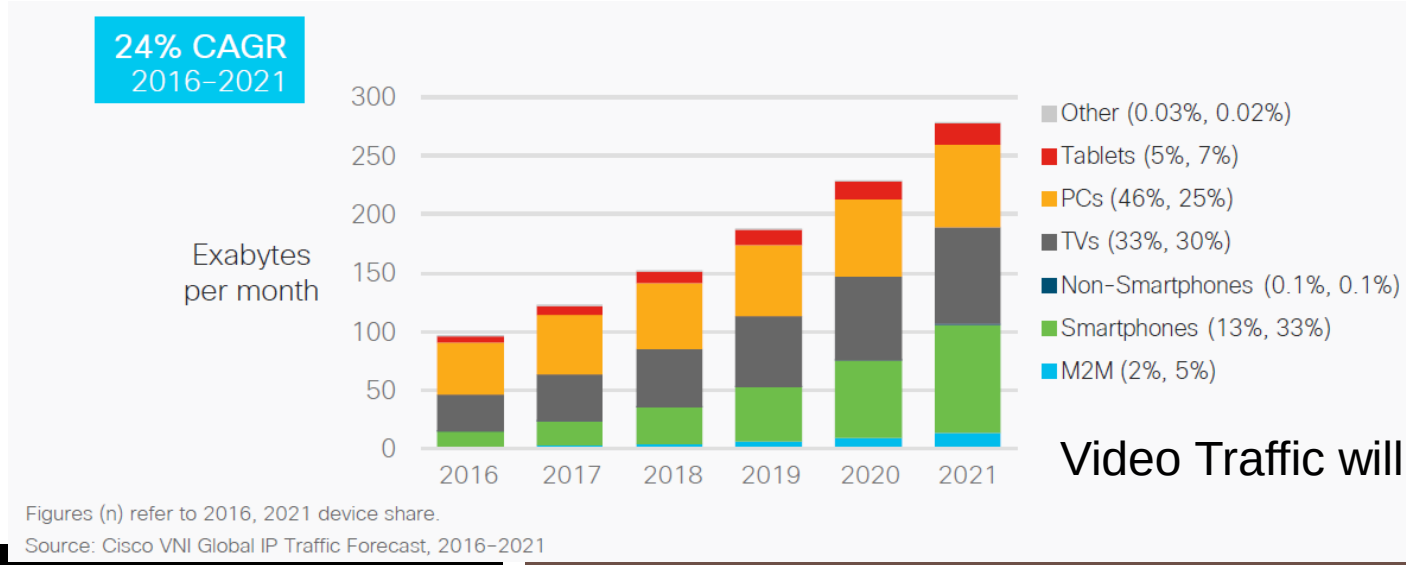
The Quest for Data



278 EB per month of IP traffic by 2021



Global devices and connections growth 25 B by 2021

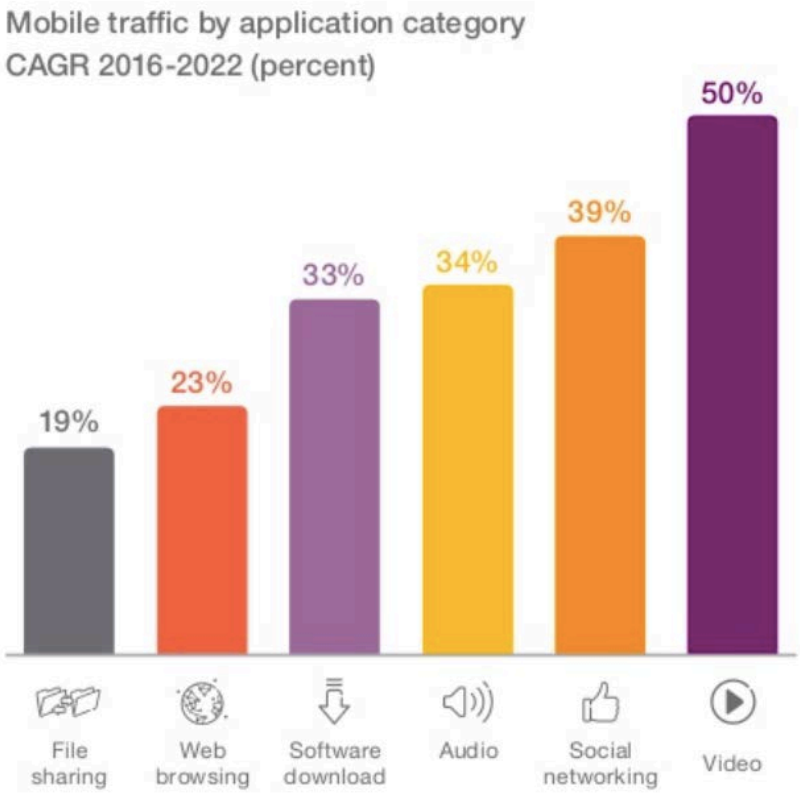


Video Traffic will dominate

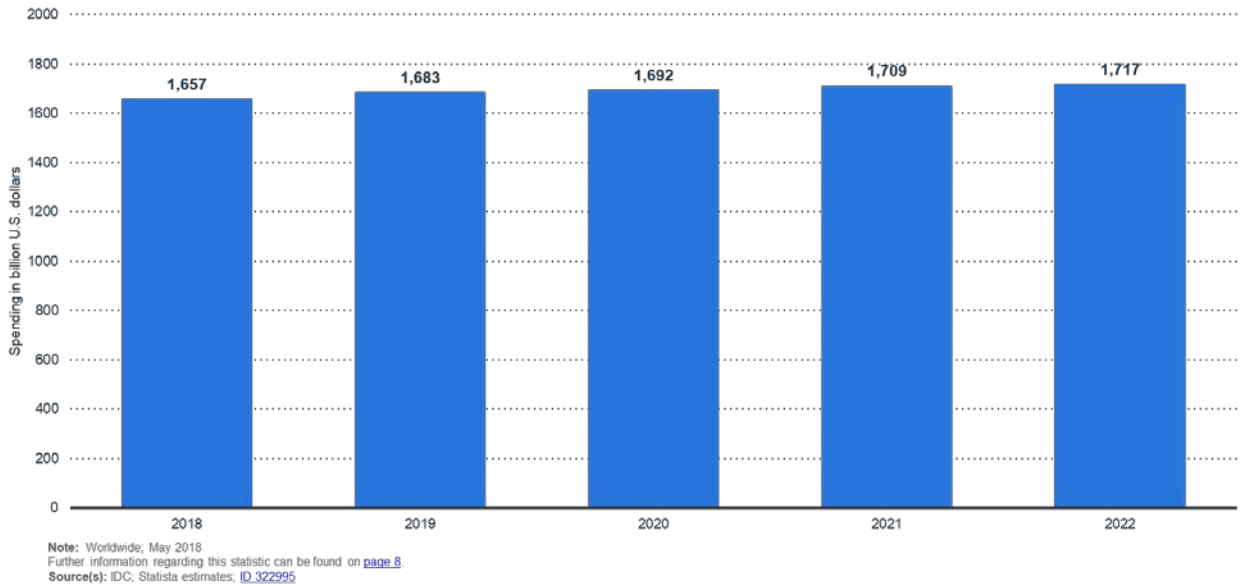
Source: Cisco VNI forecasts

Mobile traffic by Category

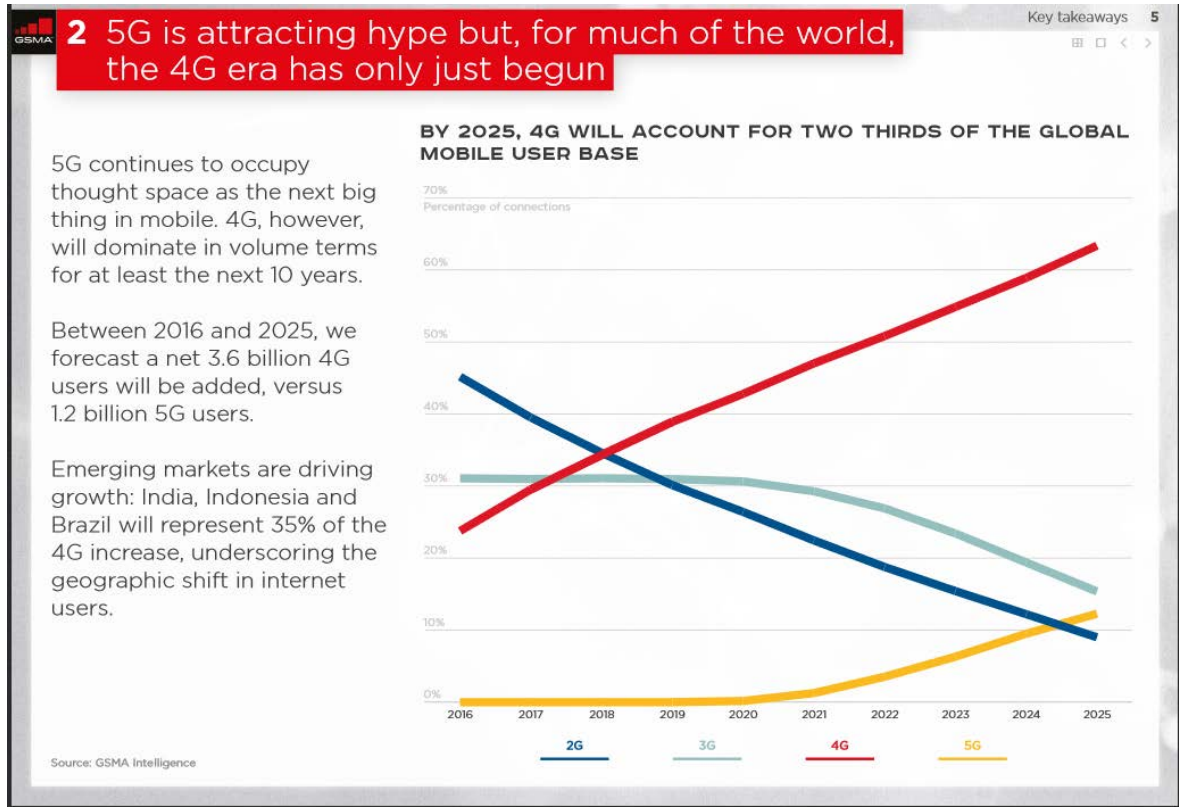
Source: http://elenaneira.com/market-report/report-to-forecast-5g-market/#.W_wjt-Io82w



Voice Still a huge market, but slowly increasing



4G vs. 5G vs. 6G



GSMA view

6G features

- **Trend 1: More Bits, More Spectrum**
- **Trend 2: Increased Emphasis on Spatial Bandwidth**
- **Trend 3: New Technologies**
  - E.g., Antennas technologies, AI, Distributed computing, …
- **Trend 4: New Applications (e.g., IoT)**

Source: IEEE What 6G will be
https://www.comsoc.org/ctn/what-will-6g-be

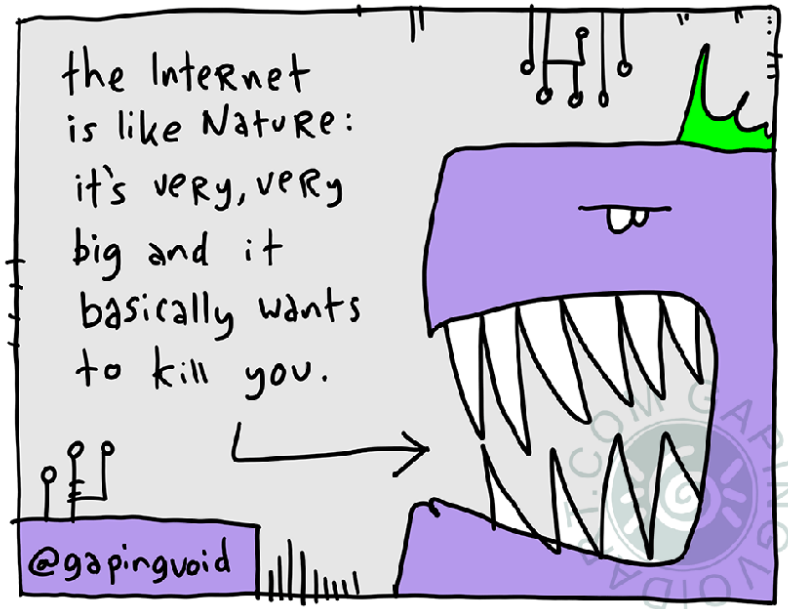
Some observations on Data Quest

- **Multimedia hunger**
  - Multimedia devices generate more traffic (e.g., smartphone, TV and game consoles)
- **M2M pervasiveness**
  - IoT devices (around 13 B) are a bit less that previously predicted (30 B – 50 B of devices)
  - They produce a smaller amount of traffic (2% to 5 %)
  - Can we define it a Massive Machine type of communications?
- **Voice is still a substantial business source, but we have definitively entered into the DATA Network AGE**
- **5G has a long way to go and so 6G**

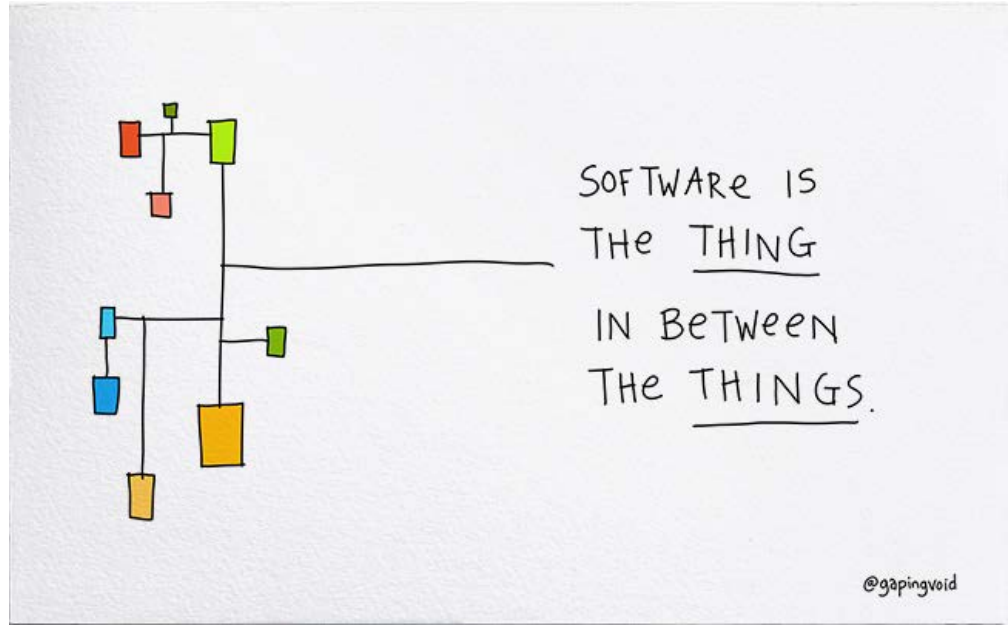
What does it mean to be in a DATA Network AGE

Two important perspectives!!!

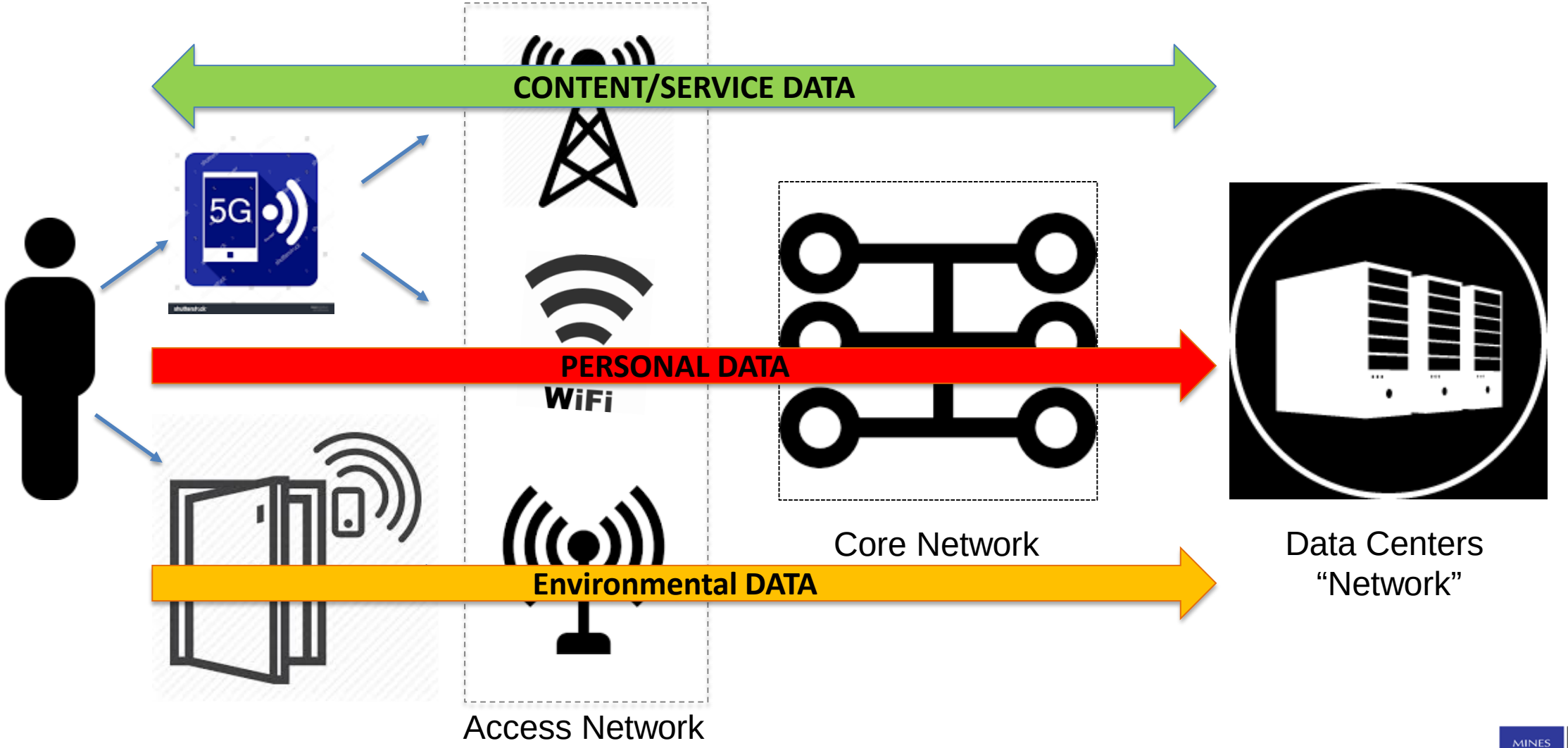
USER view



SW view



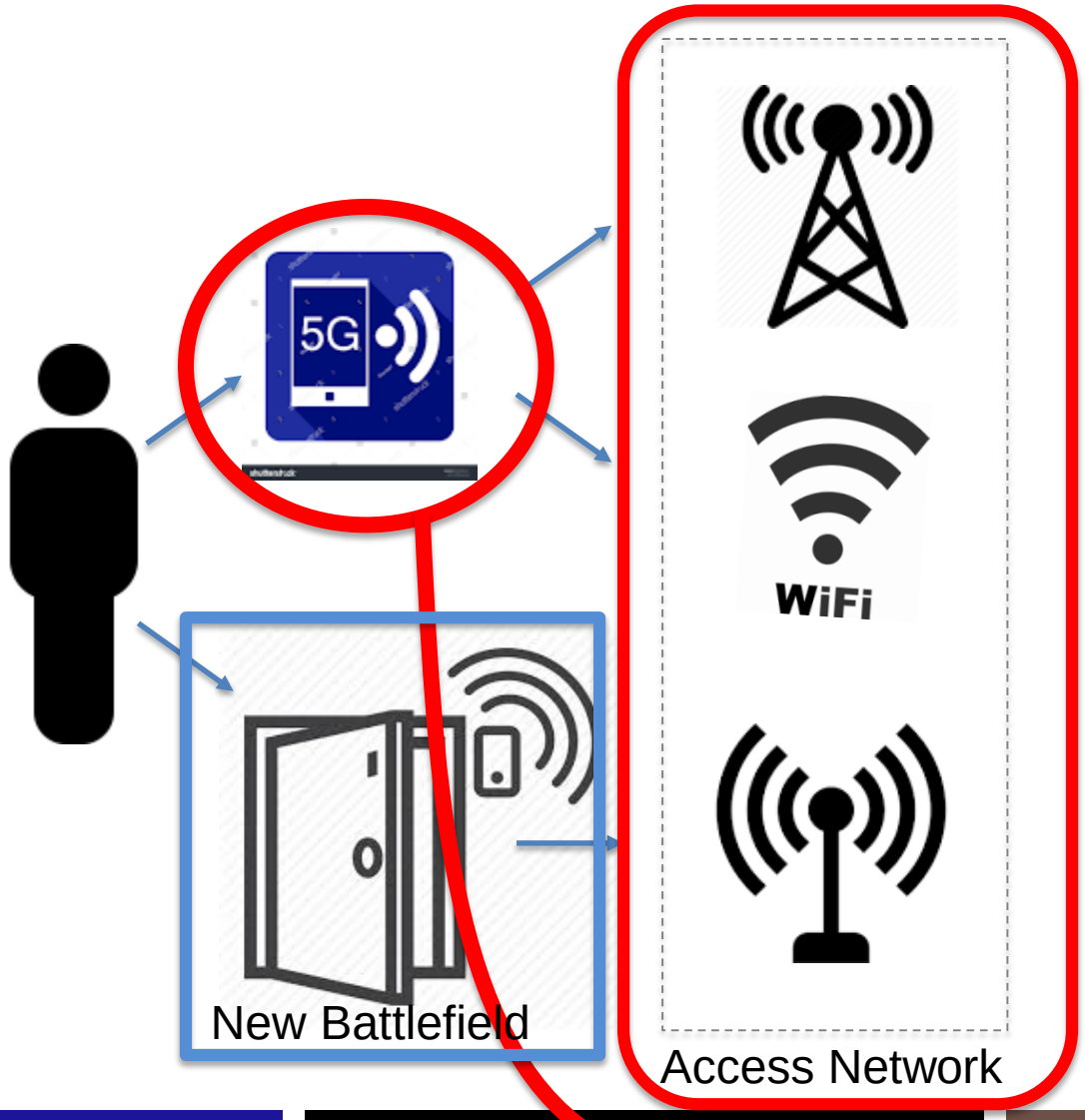
The DATA QUEST with USER EYES: three flows of data

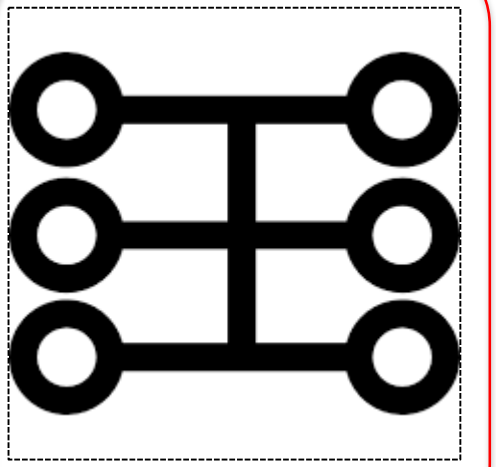


Network Choke points

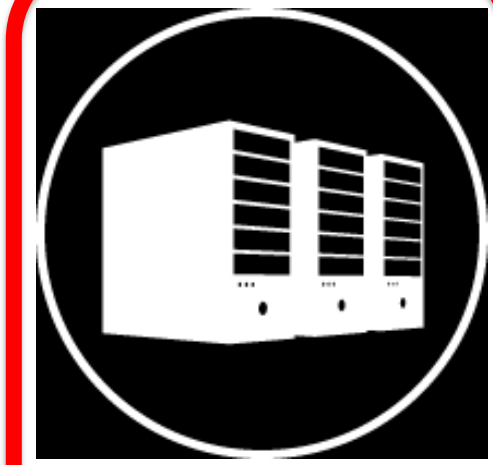
Definition: A CHOKE POINT IS ANY narrow passage that restricts traffic. It literally connotes a location where the flow could be choked off.

Source: http://geography.name/choke-point/





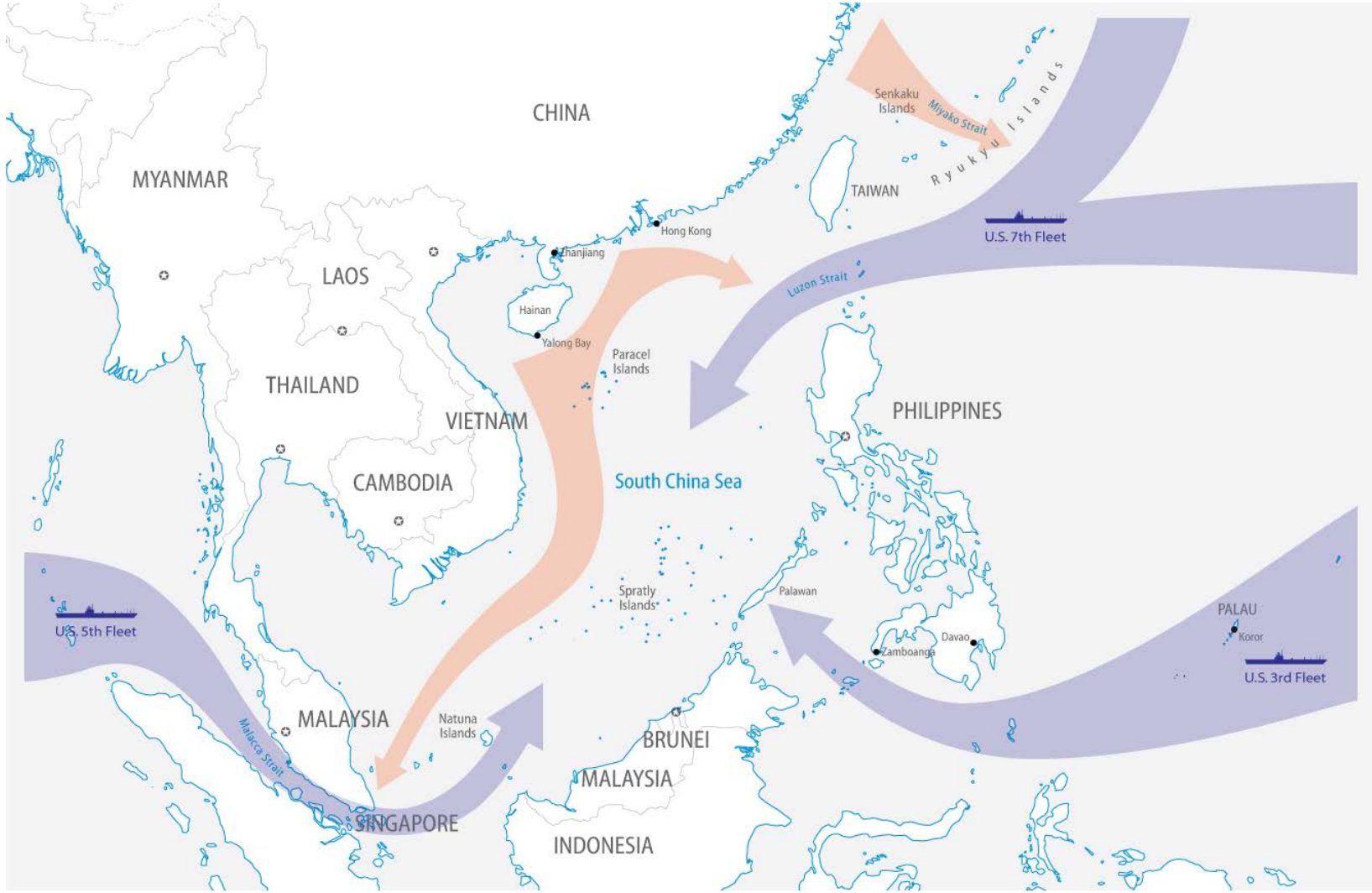
Core Network



Data Centers
“Network”

Terminals + Services / Applications = closed ecosystems

Importance of Choke points: US Navy blocking China



Source: https://medium.com/@Rutgersson/naval-chokepoints-the-chinese-conundrum-2a4ee563cab0

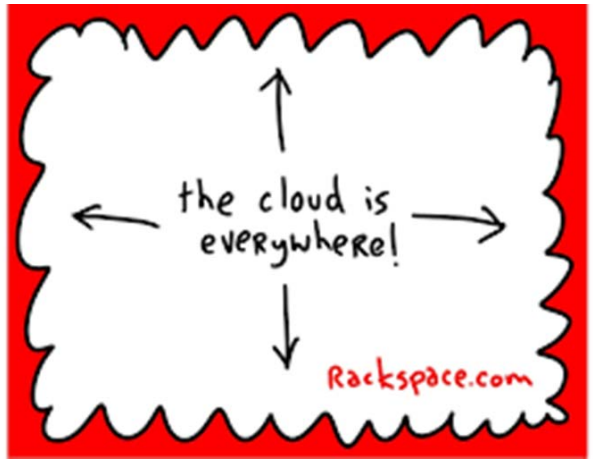
Some considerations

- **Why there are not open hw terminals?**
- **Why Cloud won over grid?**
- **Choke points are technical or business issues?**

- **Some challenges for the Next Generation Internet could be:**
  - Can we build a flat network without choke points?
  - Who should be in charge for it?
  - Should the role of Users and Society be considered?

But there are more (choke points) !!!

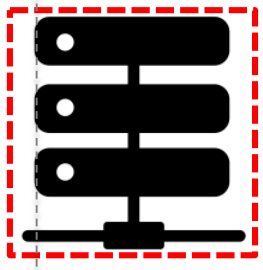
EDGE COMPUTING

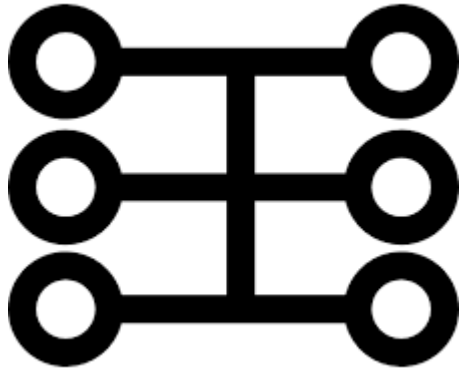


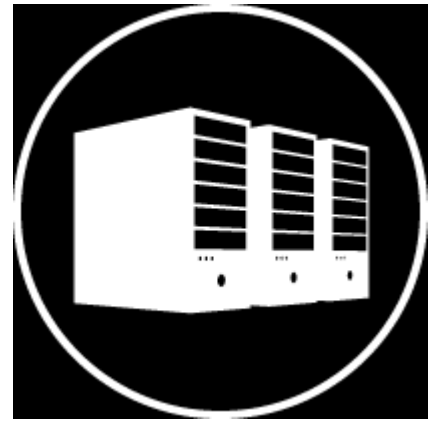
Edge Computing Instantiations

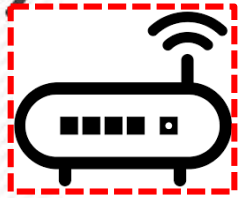
FOG

MOBILE EDGE







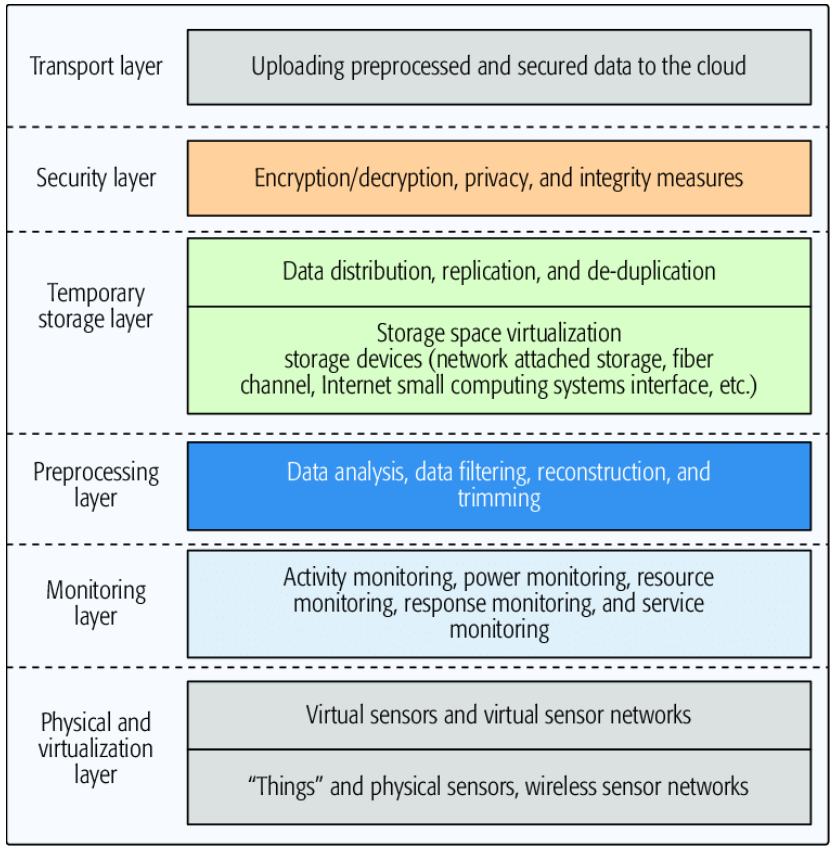


GTW

Access Network

WHY ?
To provide local processing (Technical)
To introduce new choke (ops sorry) control points (Business)

FOGging the data



Aazam, Mohammad & Zeadally, Sherali & A. Harras, Khaled. (2018). Fog Computing Architecture, Evaluation, and Future Research Directions. IEEE Communications Magazine. 56. 46-52. 10.1109/MCOM.2018.1700707.

Why

- **Local Data Analysis**
- **Data Storage and Data Recomposition**
- **Security**

… but

- **Preprocessed data may lose their value. We may need raw data to identify patterns**
- **What services will be provided by FOG?**

On the other side

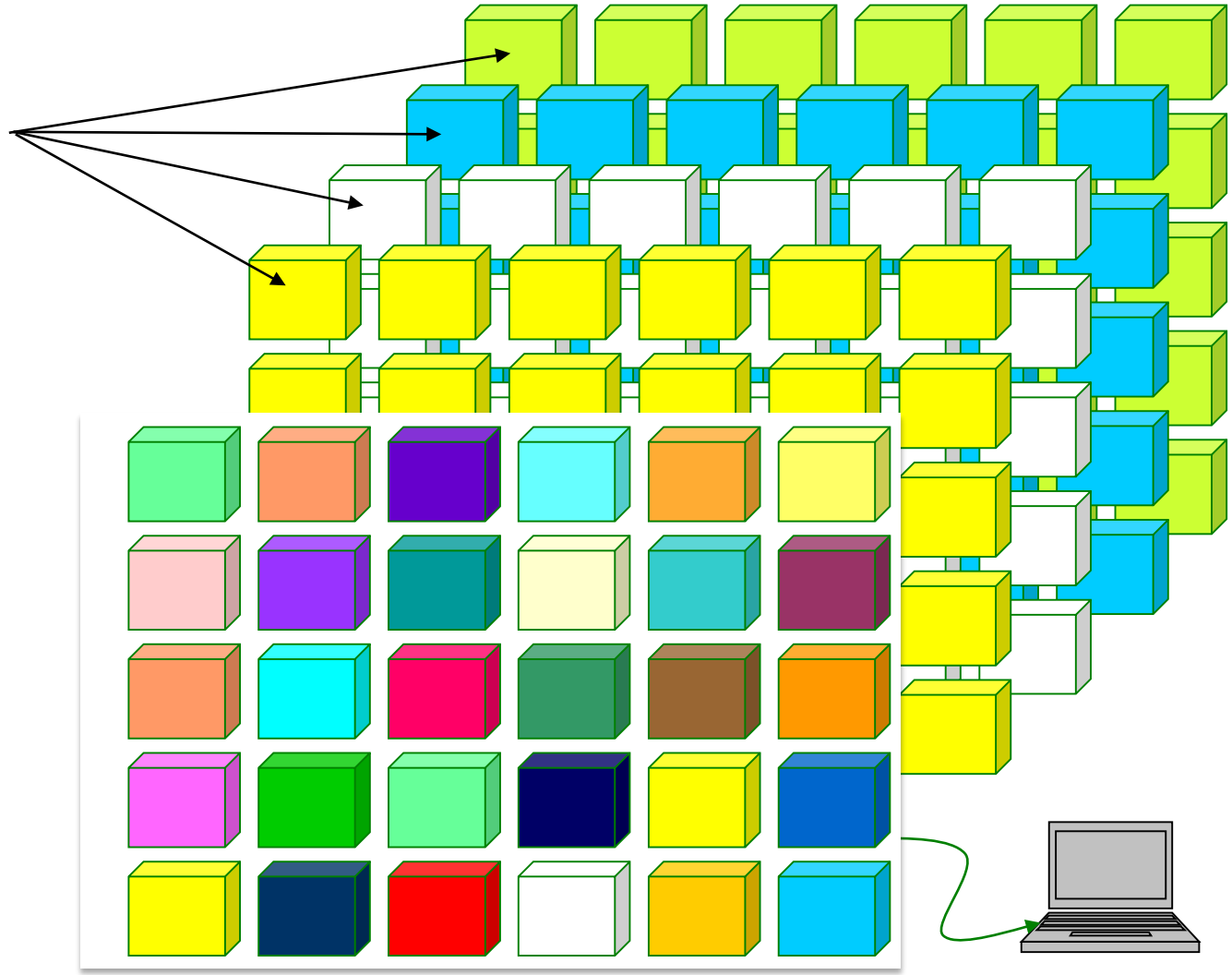
- **Fog computing is very close to highly distributed processing, peer to peer**
- **Highly disruptive if well used**

Edge computing vs. cloud

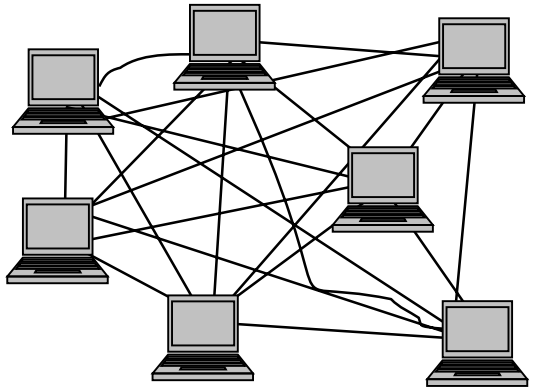
CLOUD:
Separate Administrative Domains
(made out of homogeneous resources)

EDGE:
Cooperating heterogeneous nodes pertaining to different administrative domains

Openness comes with a Price: Complexity



Edge vs. Cloud Computing



Capacity (Adaptive System) = $\sum (b_i, s_i, f_i, p_i)$

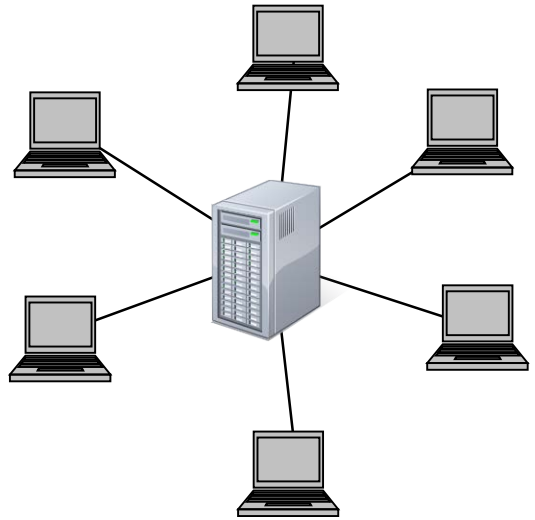
Where:
b_i = bandwidth of node i
s_i = storage of node i
f_i = files of node i
p_i = processing of node i

Optimization is a problem

Capacity (Client-Server System) = $\{b_S, s_S, f_S, p_S\}$

Optimization is a function of a business model

Where:
b_S = bandwidth of the Server System
s_S = storage of the Server System
f_S = files stored in the Server System
p_S = processing in the Server System



Edge vs. Cloud Computing

- **Some issues and challenges**
  - How much processing / storage in the edge?
  - What services and applications at the edge?
  - What advantages for the USER?
  - Is there a possibility to be an alternative to other networks?

- **It is not only a technical matter of how to optimize the distribution of processing, storage, communications and sensing: Edge is another Choke Point**
  - Depending on the winners, the edge will be more or less integrated with the Cloud
  - Its implementations will be more or less open and programmable

- **It is hopeful to have an open APIs based approach for EDGE definition in order to progress towards a full programmable network**

The IoT Flood

Initially the worry was … will IoT generate a deluge of data? Is it the case?

How much data for IoT?

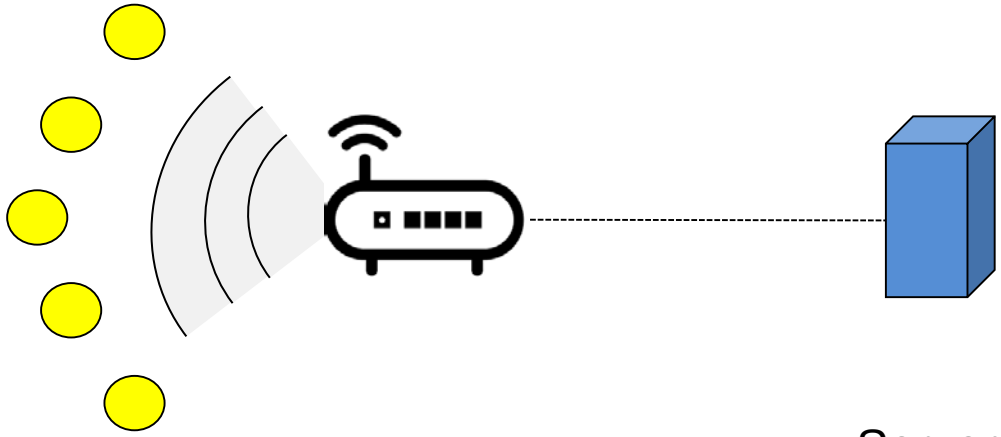
What types of data ?

The role of edge and gateways?

A simple Communication Perspective

Low Range Technologies

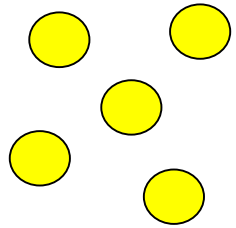
Wide Area Network Technologies



Sensors

Gateway / Mediation

Servers



How many Sensors ?

How many Gateways ?
(or how many edge networks?)

How many Messages?
How large?

How much bandwidth for IoT ?

The Gateway Effect

- **Data Sources**
  - Sensor data rate generation strongly depends on the sensor and the specific application. When the number of sensors grows the aggregate data generation rate grows
  - Data load increases with the size of the payload (some sensors can generate small amount of data with a high rate)
  - Multimedia sensors (e.g., cameras) tends to generate large streams of data
  - When the Δt between two messages → 0 then the sensor/gateway generates a stream of data
  - Streams of sensor data can exhibit similar patterns as multimedia data, but sometimes they have different requirements
  - Number of «streaming IoT devices» can have a huge impact on network
- **Mediation**
  - When many sensors are mediated by a Gateway, then
    - Messages may be processed and reduced in quantity (aggregation)
    - The rate of outgoing messages from GW to Server may be high and may generate a stream
- **Sensor behaviour**
  - Some IoT systems exhibit impulsive behaviours
    - A Container Ship with M2M devices entering in a harbor generates a spike of signalling and data
    - An alarm generated by several sensors in a specific are
    - Malfunctioning: a sensor that generates many messaging and stresses the nearby resources
- **Data Collection (data sinks)**
  - Data generated by sensor may be stored and processed locally (edge computing) or transfered as raw data over the network
  - Data sets of raw data can be very useful to study particular phenomena, but transfer them to cloud systems could be «expensive» or against the logic of Edge

Bytes per Object (Sensor) per Day

Messages per day		Message length in Bytes						
		1	8	64	128	256	512	1000
1 per day	1	1	8	64	128	256	512	1000
1 per H	24	24	192	1536	3072	6144	12288	24000
1 per min	1440	1440	11520	92160	184320	368640	737280	1440000
1 per sec	86400	86400	691200	5529600	11059200	22118400	44236800	86400000
1per 500 ms	172800	172800	1382400	11059200	22118400	44236800	88473600	172800000
1 per ms	86400000	86400000	691200000	5529600000	11059200000	22118400000	44236800000	86400000000
	in Mbytes	86,4	691,2	5529,6	11059,2	22118,4	44236,8	86400
	in Mbps	0,008	0,064	0,512	1,024	2,048	4,096	8

Peer to peer **Video Streaming**

Smartphone average data consumption

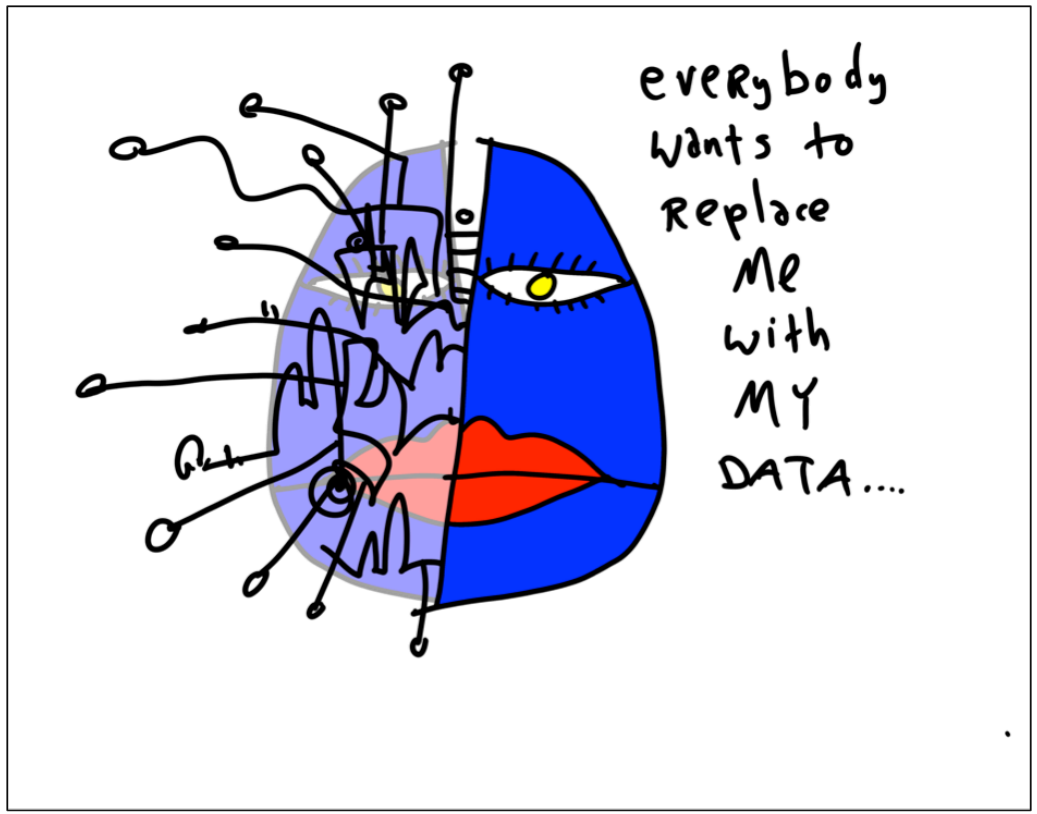
	in Gbyte	in Mbyte	Mbytes per day
Western Europe	**1,9**	**1900**	**63,33333333**
USA	**3,7**	**3700**	**123,3333333**

Source Ericsson: https://www.ericsson.com/res/docs/2016/ericsson-mobility-report-2016.pdf

The IoT Flood

- **Need to learn how IoT Systems will generate, handle, mix or even limit, cut, reduce streams of data**
- **Raw data vs. pre-processed data**
  - Do we need raw data ? If yes how can we get those in an economical way? Can fog systems pre-process the data but also keep the raw data? When to transfer the raw data for back-end processing?
- **How much IoT data will be too much?**
  - Can we lose alarms?
  - Can we limit the data flow from sensors to the cloud with Digital Twins?
  - Who is the owner of these streams of data?

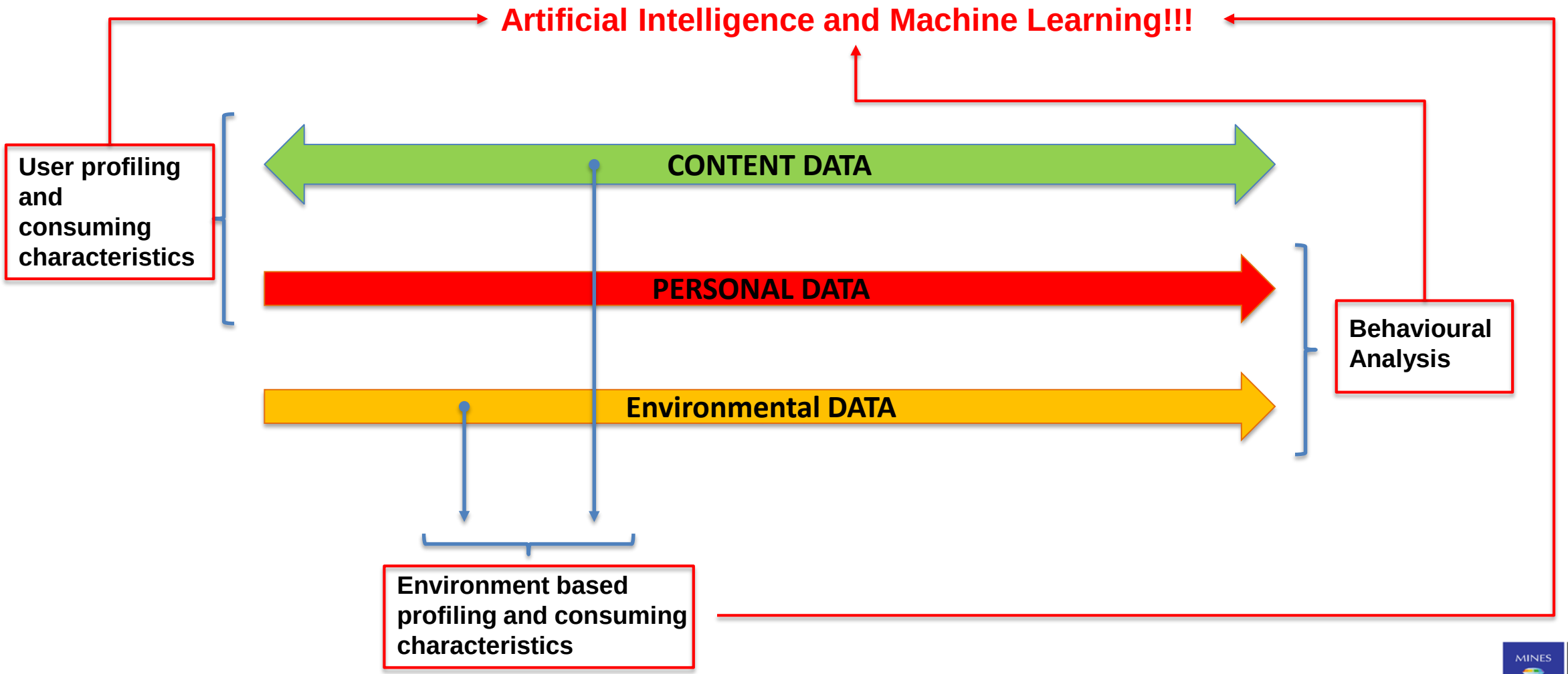
Data Centricity and the User Data



Users are not only received and sent data
Or personal profiles

Networks are now strongly associated to personal behaviour and social aspects

Let's go back to the three data flows



IoT Data and … Identity of Things

Things have Identities (and Owners) People have Identities and use Things

"My" Smart Thing

Identity Relation

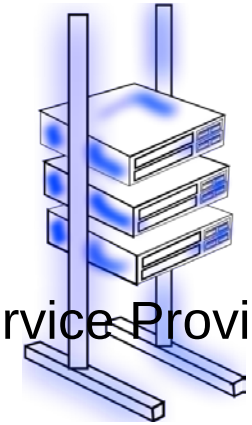
Me

Identity Relation

SENSOR

Functional Relations

(events and commands)



Service Provider

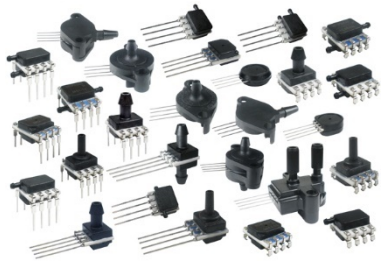
Personal Profiling

Who, Where, When, What, Why, …

Aggregating Data per Identity …

- Who is the Owner of all these Data ?
- Who has the right to extract info ?

"OUR" Smart Things



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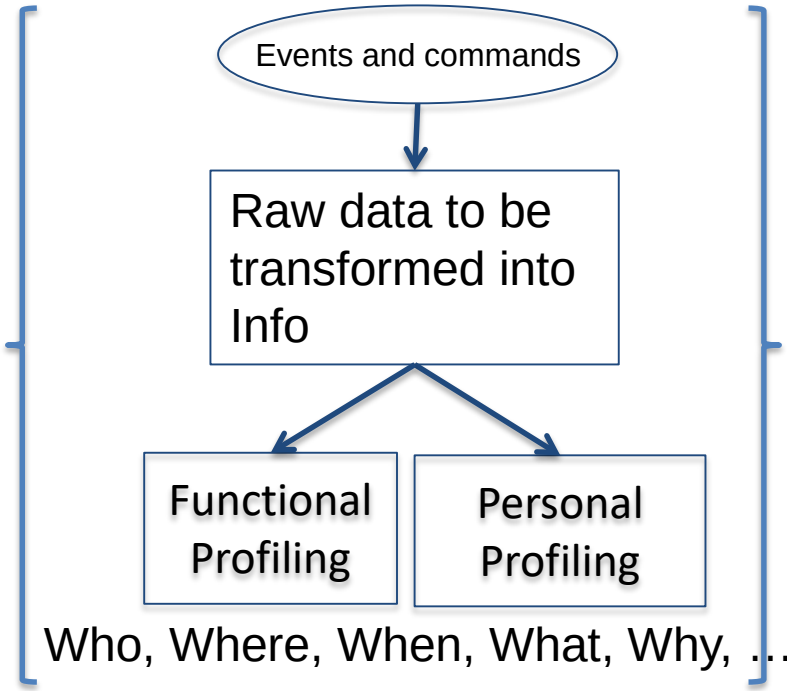

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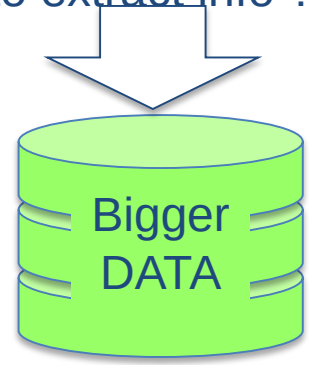
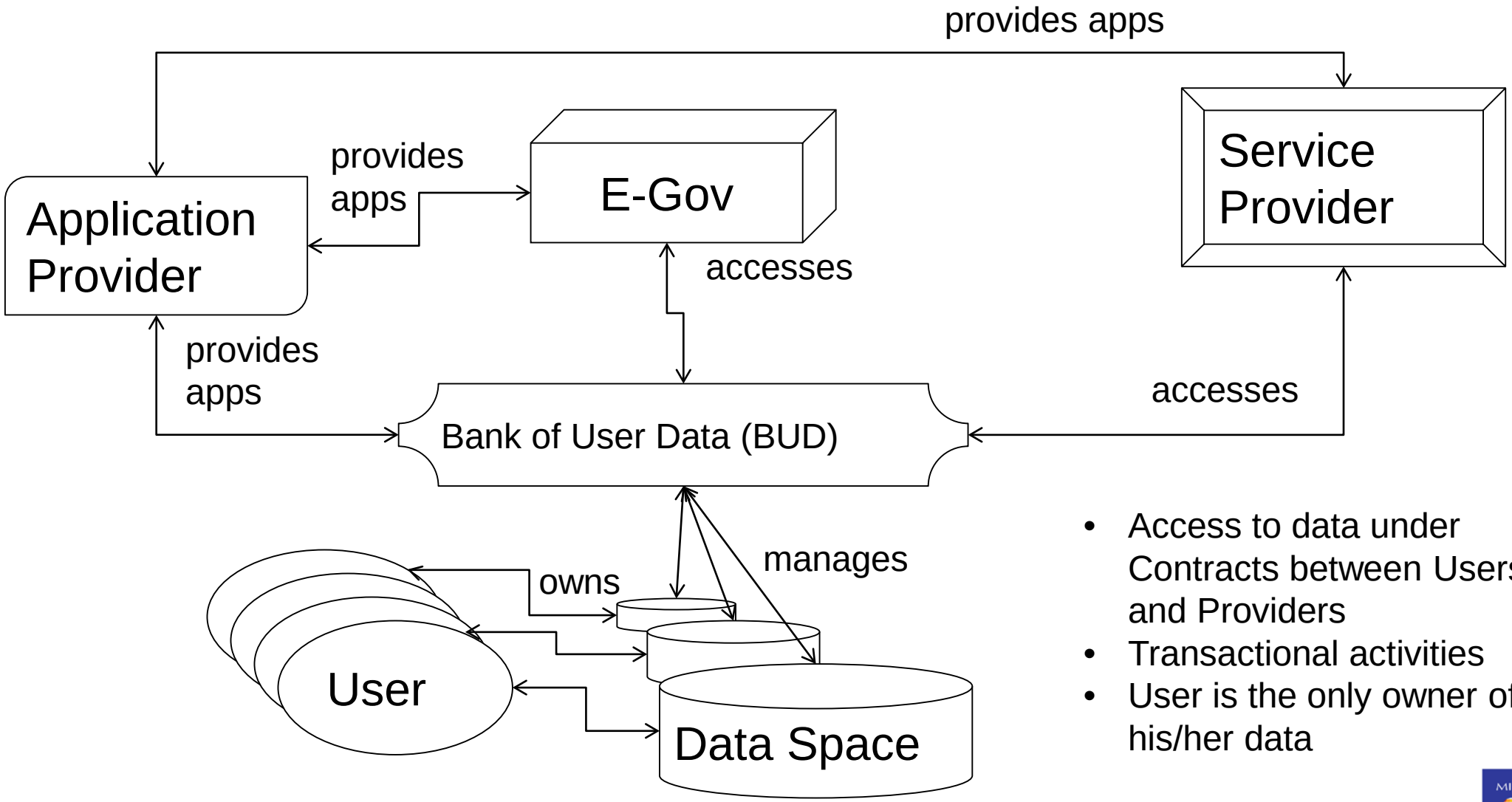


50 B Devices * ~ 2MB/day = ~ 88.81 petabytes /day

(Average Aggregated Traffic of M2M Devices)

The Bank of User Data

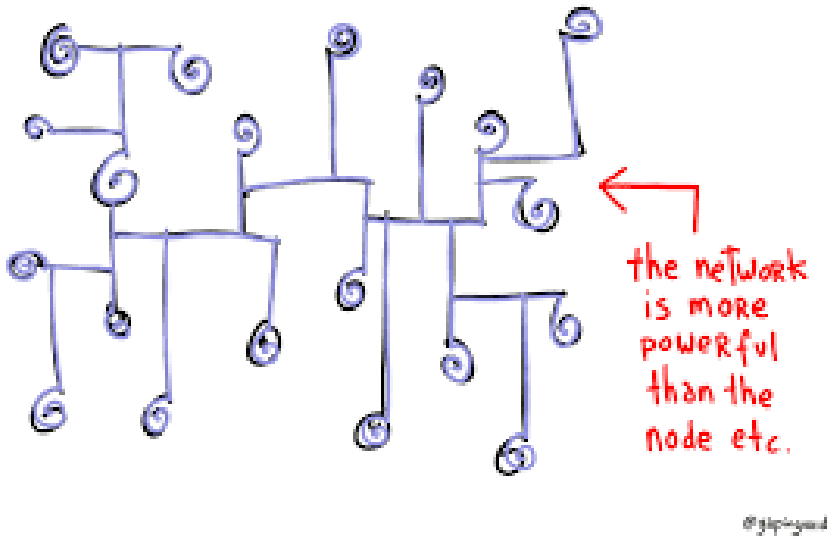


- Access to data under Contracts between Users and Providers
- Transactional activities
- User is the only owner of his/her data

User Data Centric vs. User Centric

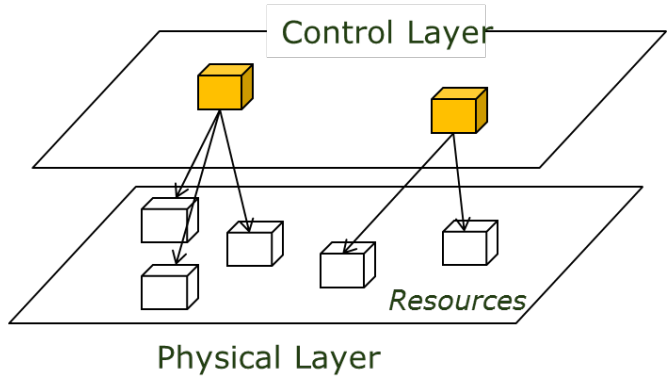
- **Behaviour of people can be “measured”**
  - Statistically or by means of AI / Machine Learning
  - Dunbar Number and identification of meaningful relationships
- **People can be induced to do things**
  - From buying stuff because of advertising to donate or cooperate
  - Ohtsuki, Hisashi, et al. "A simple rule for the evolution of cooperation on graphs and social networks." Nature 441.7092 (2006): 502.
- **Analysis and mining of personal data is a major social issue**
  - Regulations (e.g., GDPR)
  - Behavioral science
  - Psychology
- **But fewer (compared to the mainstream) research is devoted to User Centricity from the user perspective (☺)**

Interaction paradigms

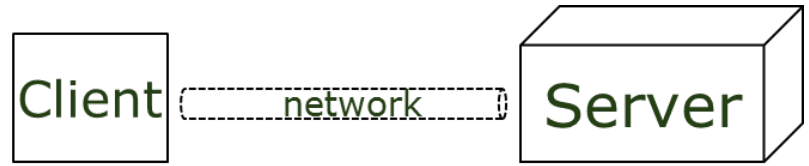


END TO END PRINCIPLE FOR IP NETWORKS:
“mechanisms should not be enforced in the network if they can be deployed at end nodes, and that the core of the network should provide general services, not those tailored to specific applications”
Saltzer, Clark, …

How Smart Objects communicate



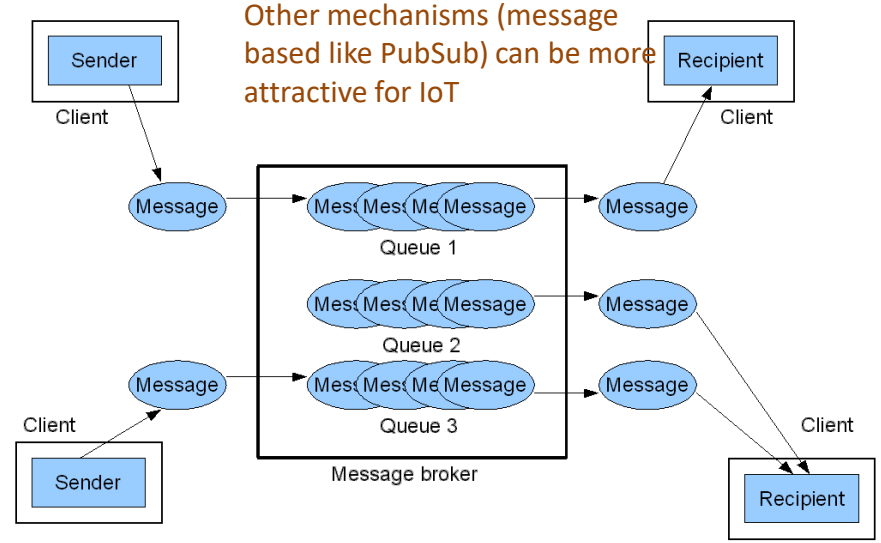
Network Intelligence (e.g., IMS) is a hierarchical model based on the assumption that control has to be exerted by a few specialized control nodes



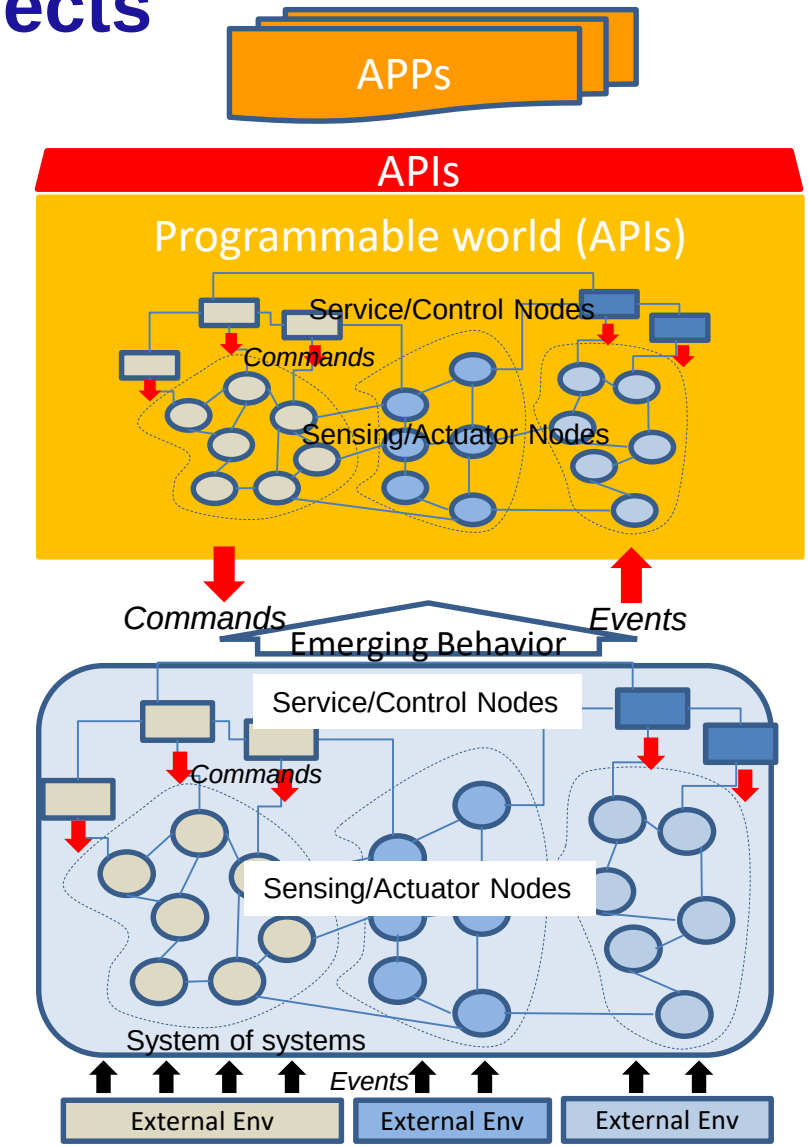
Client – Server model disregards the network aspects and can lead to a tragedy of commons (misuse of common networking resources)

This is a reason for different protocols …
Is it there a single communication paradigm for NGI ?

Other mechanisms (message based like PubSub) can be more attractive for IoT



Softwarization of everything: physical and logical Objects



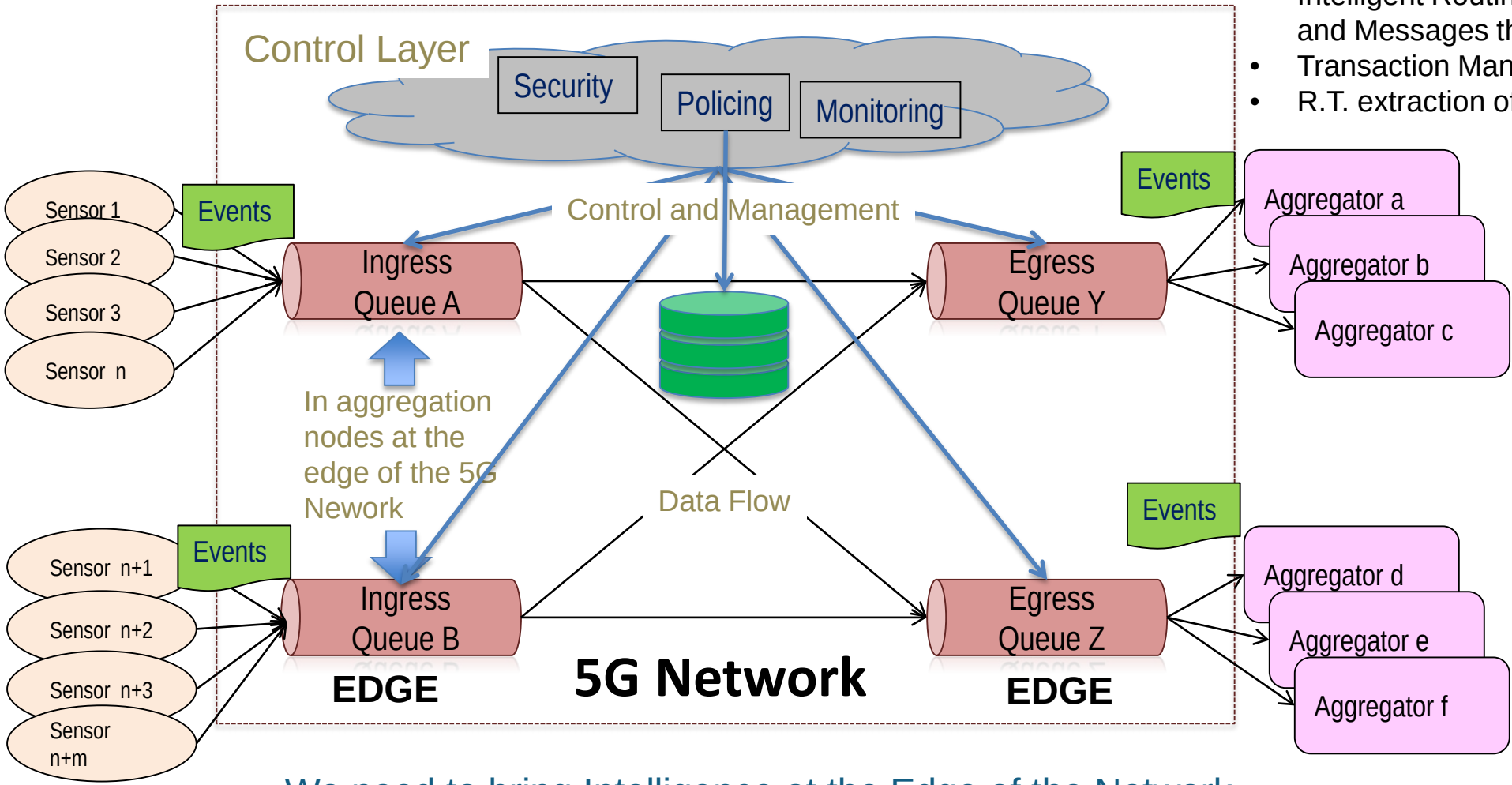
A new paradigm of interaction?

- Each Virtual Object should come with autonomic properties, i.e., self management
- Each individual object could be controlled procedurally
- Each object can be extended
- Each object comes with its history
- Each Object can be replicated and supported as many as possible applications (slicing / personalization)
- The System can be programmed in the large

- Additional research Topic: can the Virtual Continuum be used to predict behavior of large systems?

Next Generation Internet and PubSub

- Intelligent Routing of Events and Messages thanks to SDN
- Transaction Management
- R.T. extraction of Knowledge

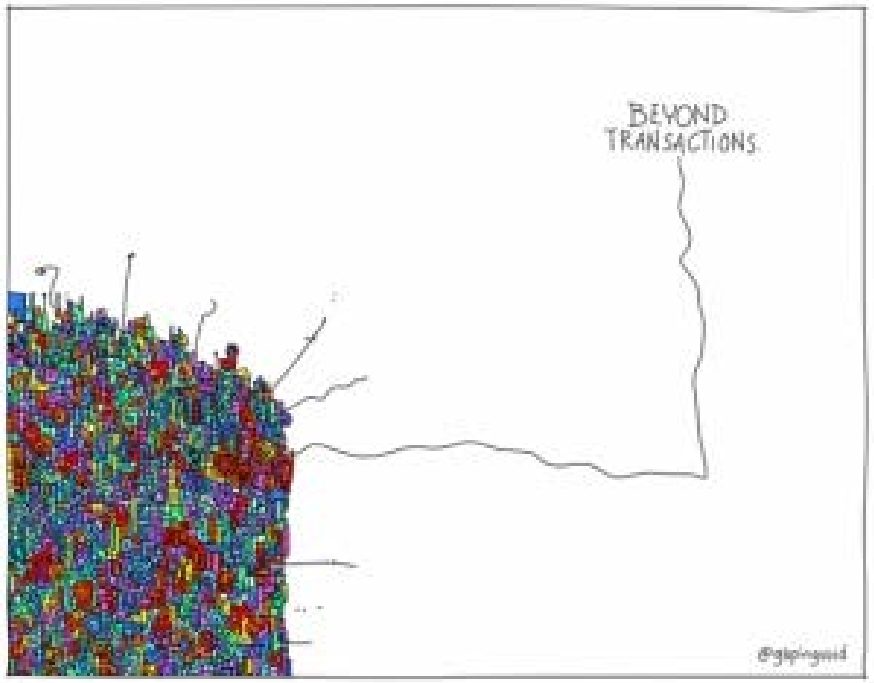


We need to bring Intelligence at the Edge of the Network

Interactions Paradigm

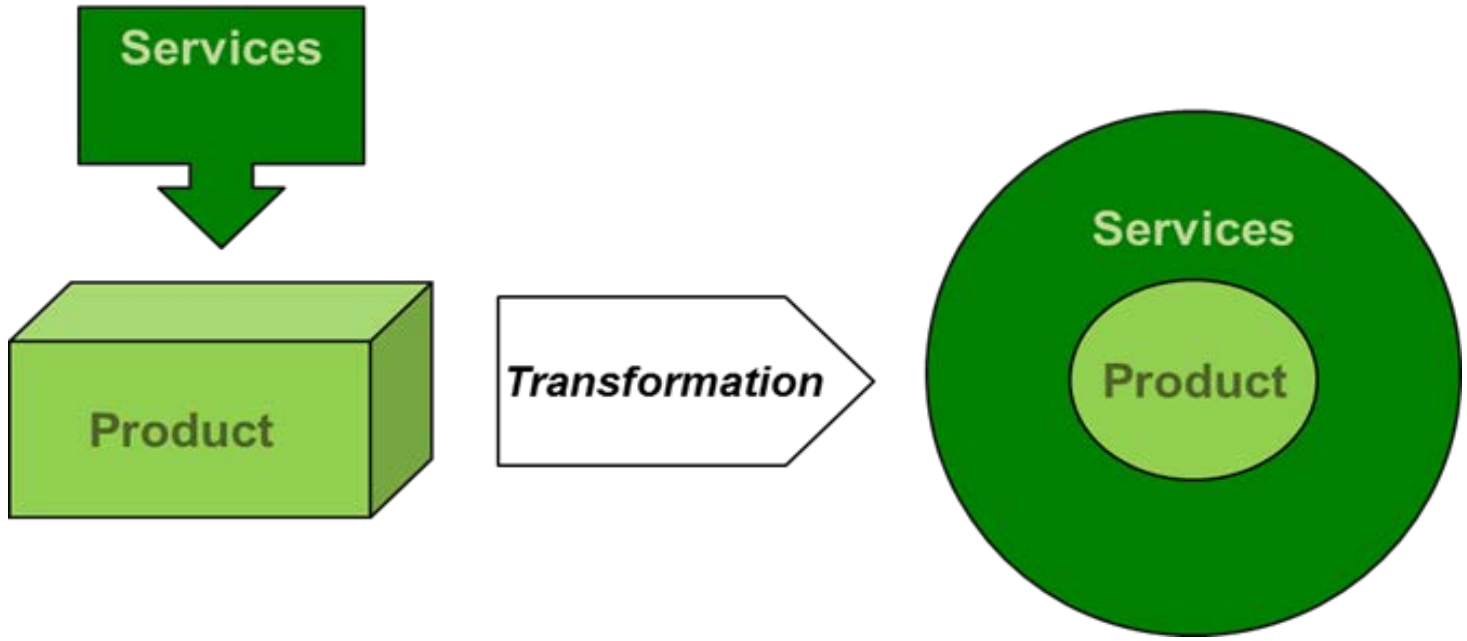
- “Client – Server” is not only an interaction paradigm, it is also a Business Model (leading to massive data centers)
- Other interactions will be needed in order to better support services and applications (and at the end the User)
- Also the concept of what is in the network and what is not is going to change
- Extensive Softwarization and Servitization may need different paradigms (e.g., entanglement) and related protocols and means
- Virtualization of objects leads at first to deal with spime (i.e., to locate objects in space and time) and then to the history of the objects and eventually to predict their future behaviour

Need for transactional interactions for empowering the Users



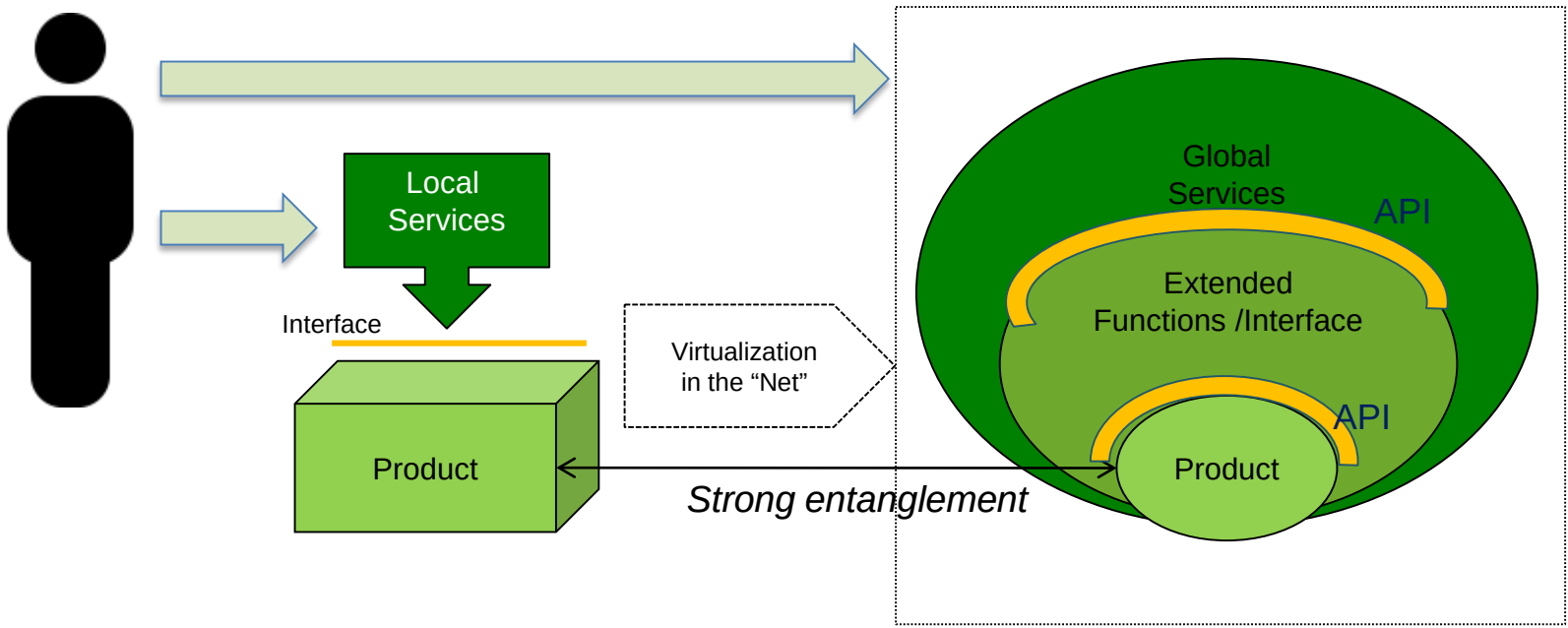
Securely and privately interaction with others
Effective and protected and guarantee transactions between users and merchants
Proved collection of activities and logs if Internet actions

Each Product will be Servitized



Servitization is the capability of creating a link between a (physical) product and a set of services and enriched functionalities that extend, complement, and add value to the product itself

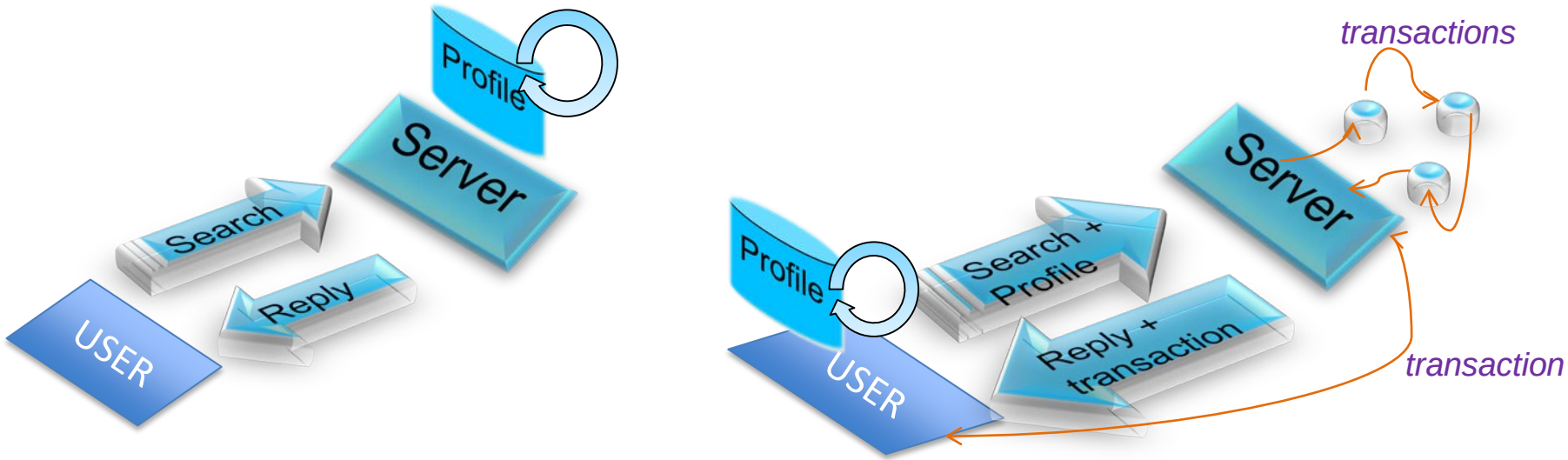
Each Product will be Softwarized



- Each Physical Resource / Product is representable by its digital twin
- Each Physical Resource becomes programmable
- Each Physical Resource can be functionally augmented
- Physical and Logical Resources must be entangled
- Users can interact with the physical and logical resource

Transactions For Important Exchange of Data

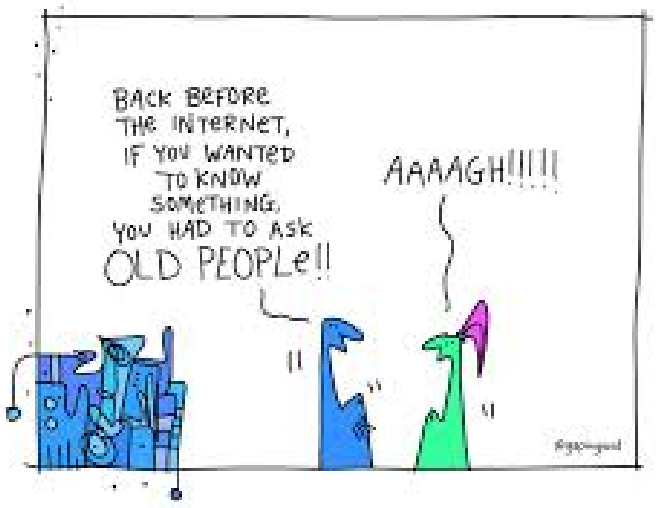
(a Receipt for every User)



- Users need to collect “receipts”, proof of their Interactions with Services, Resources and Functions
- Transactions should be stored and should contain relevant information about the data and the scope and results of the transaction
- The transaction should be carried out within guaranteed QoS parameters
- Security and privacy will be absolute requirement

- Possible usage of decentralized DB or blockchain (e.g., to be investigated in order to reduce complexity and time response)

Recap



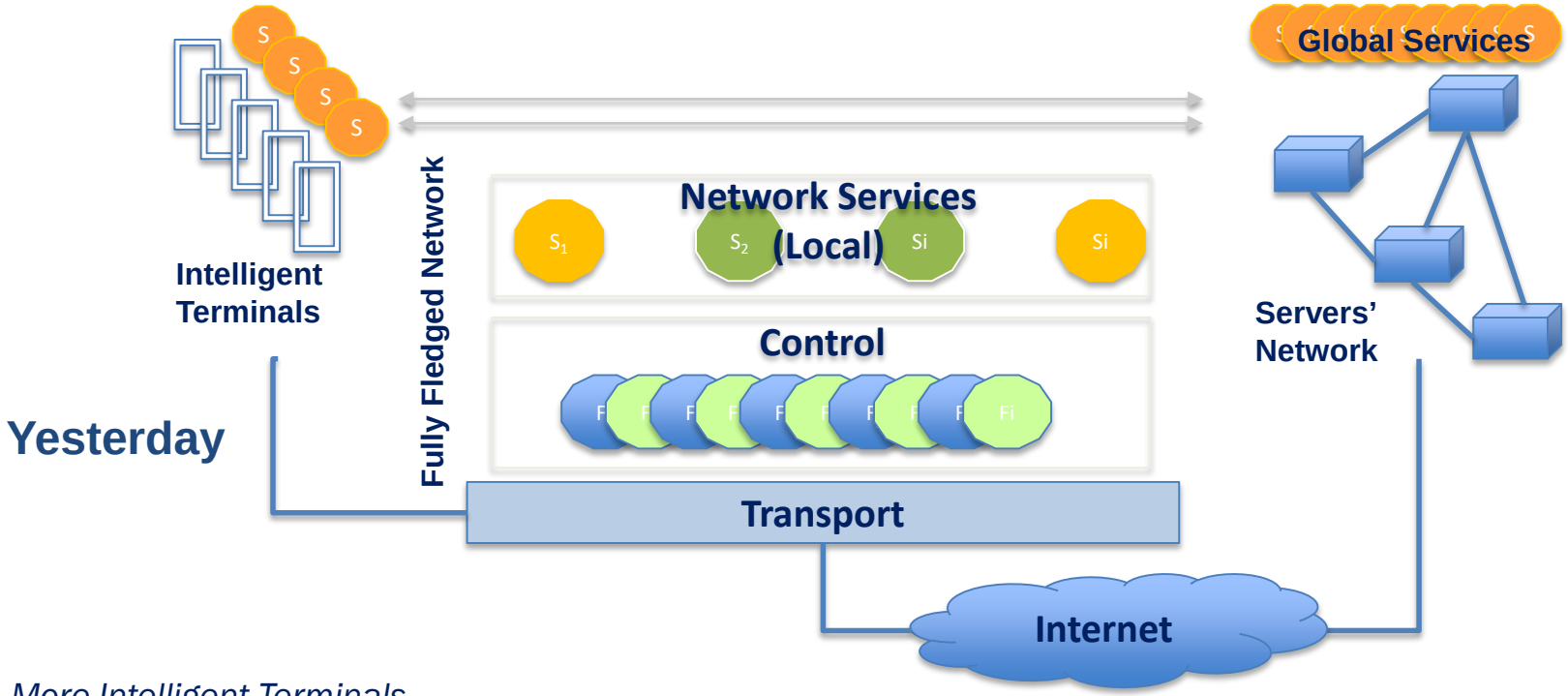
- Challenges of Next Generation Internet are Technological, but essentially Business and Social

- Focus on Users
  - User, Citizen or Customer? A great difference
  - How to create a user centered network? Because what we are working on is not User centered (It is old business centered)
  - Who will own data and infrastructures?

- NGI as a container for all
  - Entanglement, contextualization and prediction of objects' behaviour and their relationships over time (past, present and future) will lead to very complex systems
  - Multidisciplinarity is a need (Behavioural science, Economics, History, …)

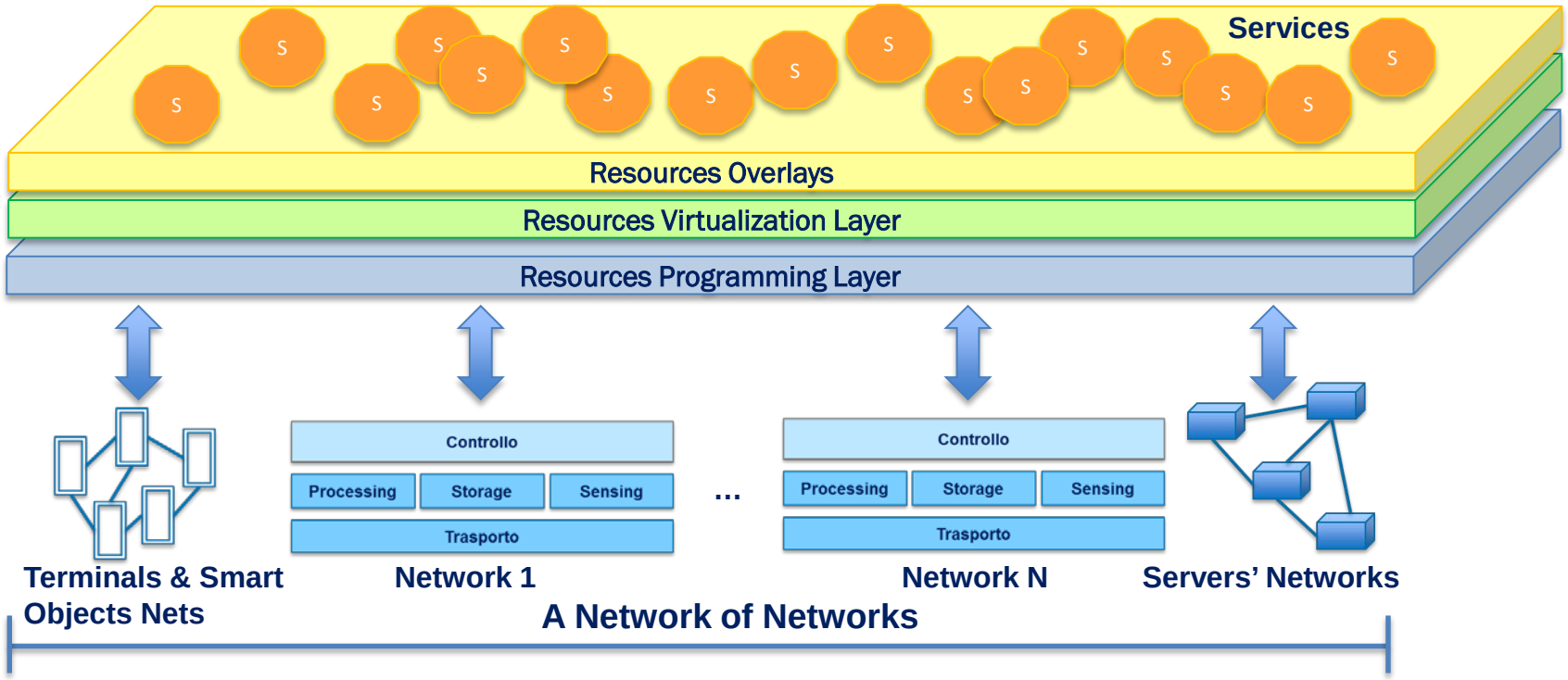
- The Next generation Internet will be essentially a software network, can it be:
  - Open source
  - Open hardware for choking points
  - Is it or will it be possible to use open technologies to create a low cost open and free access network? Is edge computing potentially disruptive?

Network Intelligence: The Past



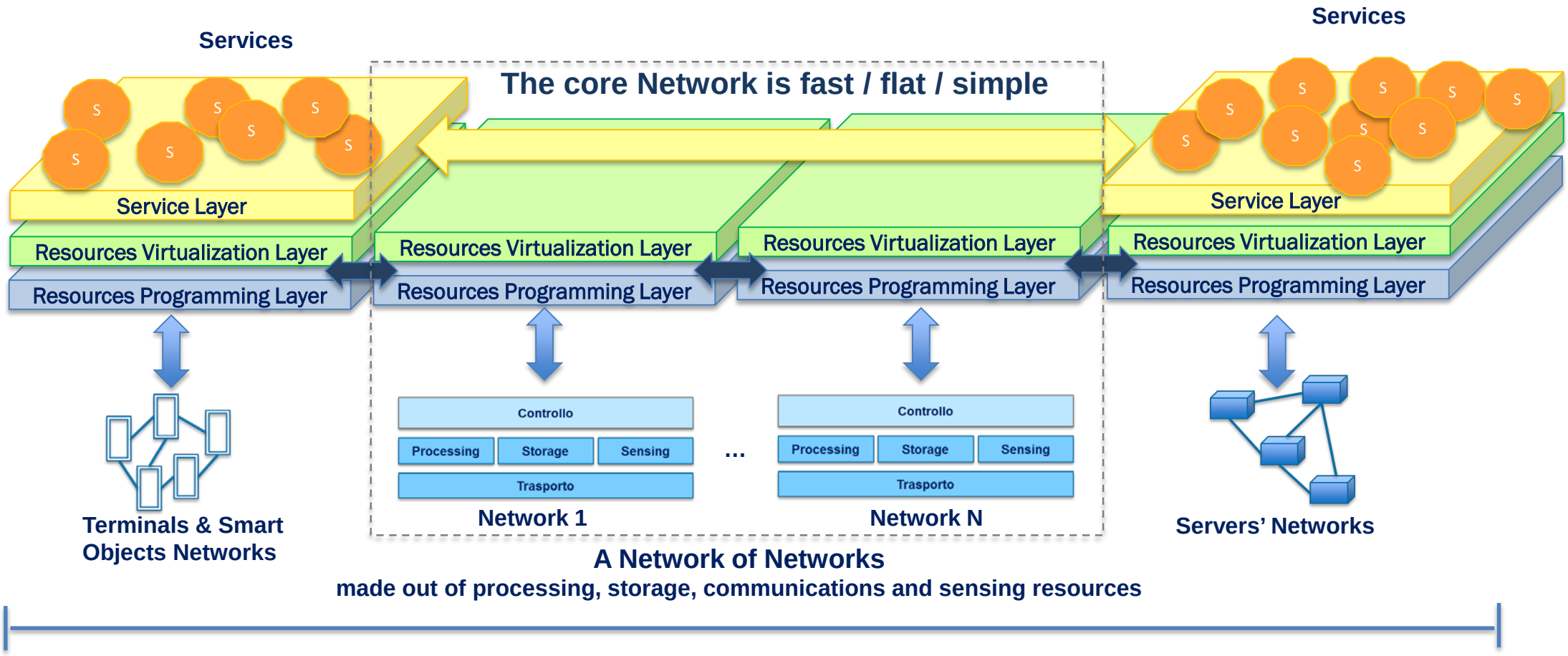
- *More Intelligent Terminals*
- *Fully Fledged Network (Many functions in the net)*
- *Development of Globally accessible Services at the edge of networks in an Internet fashion*
- *Bypass of advanced or rich Network Services (e.g., QoS)*
- *Lack of cooperation between Service and Control/Transport mechanisms at the Internet level*

Network Intelligence: the Grand Plan (e.g., 5G)



- *Terminals as Network Elements*
- *Functionally Rich Networks with strong integration of ICT functions*
- *Programmable Resources and Networks*
- *Virtualized and Aggregated Resources in Overlays*
- *Development of Global services and functions*
- *Harmonization between Services and Resources Layers*

The New Network: a Software Network with intelligence at the edge



Grazie Thanks Merci

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