

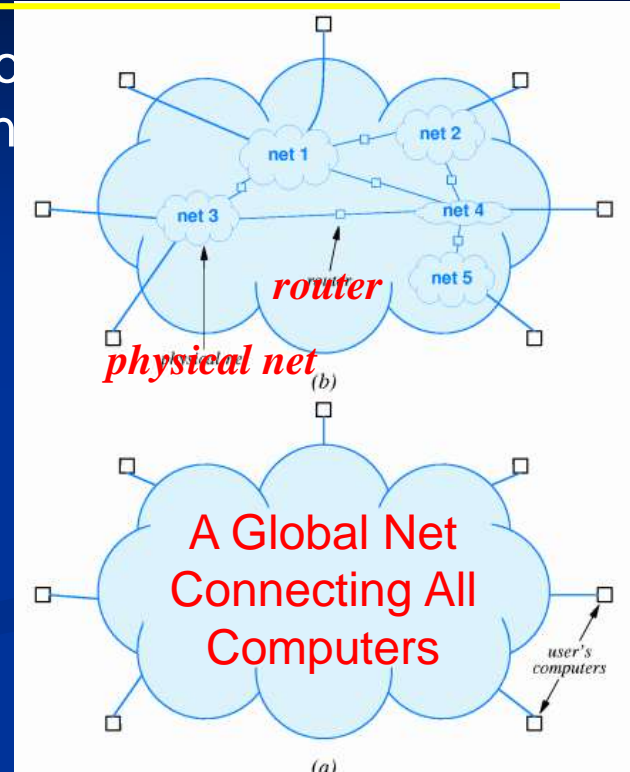
# Lecture 11

## Internet of Things (IoT) Web of Things (WoT)

- What are Internet of Things (IoT) & Web of Things (WoT)?
- Characteristics of IoT/WoT
- Potential Applications of IoT/WoT
- Technical Challenges of IoT/WoT

# What are the Internet?

- **The Internet ... a Network of Networks** that connects private, public, academic, business, and government networks at local to global scope. - *From Wikipedia*
- Originated from the ARPANET around 1970  
Available from 1980, got popular from 1990.
- Key components
  - Hardware: Routers connecting networks
  - Software: TCP/IP protocol suite, IPv4 → IPv6
  - Addressing:  $2^{32}$  (IPv4) →  $2^{128}$  (IPv6)
  - Naming: DNS → symbolic names



## The Internet → Internet of Computers (IoC)

Leonard Kleinrock



Lawrence Roberts



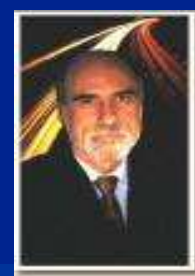
Jon Postel



Steve Crocker



Vinton Cerf



Robert Kahn



# What are the Web?

- **The World Wide Web**, abbreviated as **WWW** or **the Web**, is a system of interlinked documents accessed via the Internet. - *From Wikipedia*
- The Web was originated from **Tim Berners-Lee** around 1990.
- The Web, like Email, is one of the services that runs on the Internet.
- Key components
  - Uniform Resource Locator (URL) & Uniform Resource Identifier (URI)
  - HyperText Markup Language (HTML)
  - Hypertext Transfer Protocol (HTTP)
  - Web server and web browser (client)

**The Web → Internet of Documents (IoD)**

1st Web  
Graphical  
Browser



Ted Nelson → Hypertext



Tim Berners-Lee



1st Web Server



Mark Andreesen

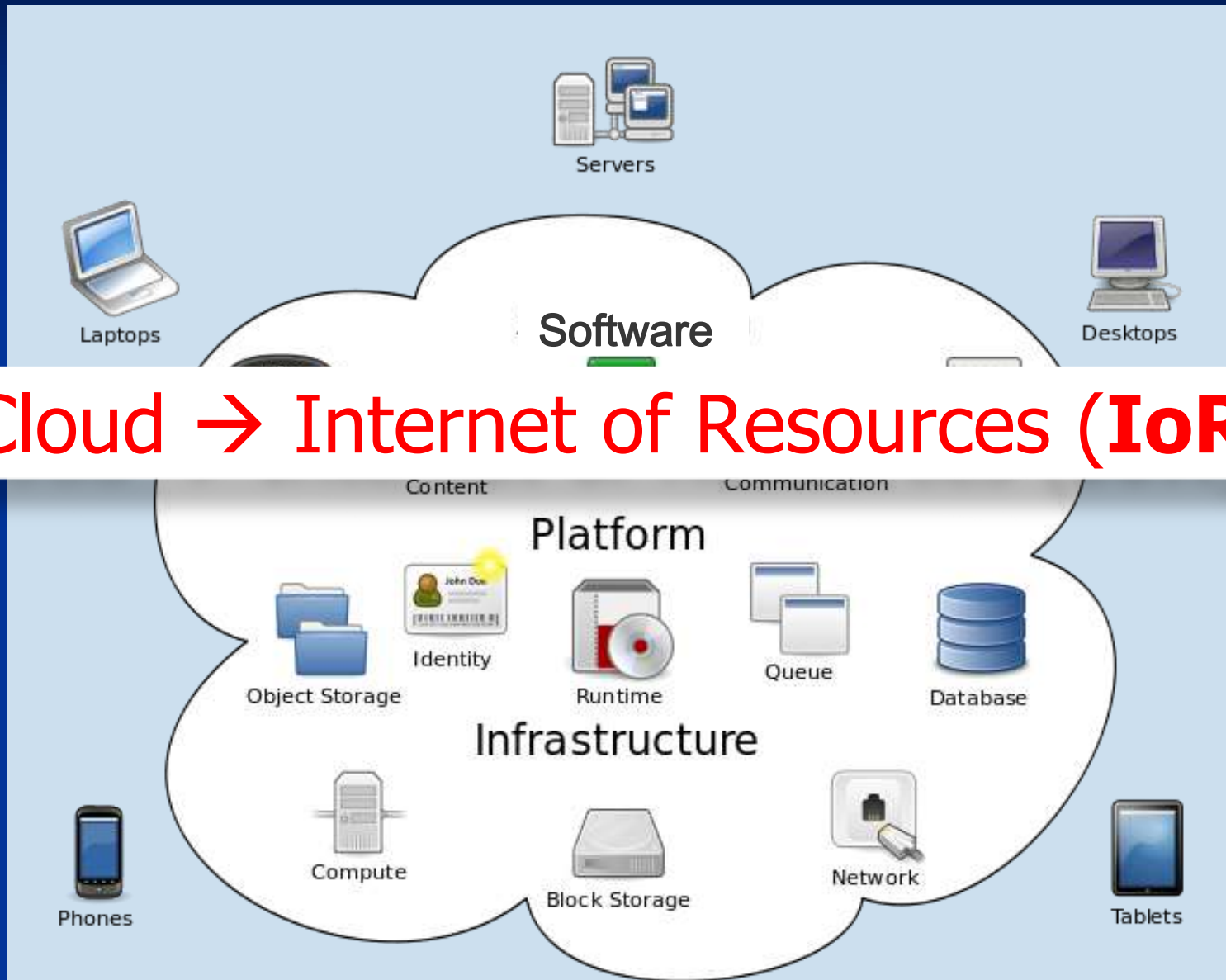


**Netscape**

# How about Social Media/Web2.0?



# How about Cloud Computing?



Cloud → Internet of Resources (**IoR**)

# What are Things?

- **Thing** - An object, an entity, an idea, or a quality perceived, known, or thought to have its own existence, ... (*dictionary*)
- **Object** – A tangible/visible thing; a person or thing seen as a focus or target for feelings, thought, etc.; a purpose/objective; ... (*dictionary*)
- **Everyday Things/Objects** – used in human daily lives
- **Inner Things** – mind, directly insensible things, ...
- **Physical things, digital things, real/virtual things, ...**

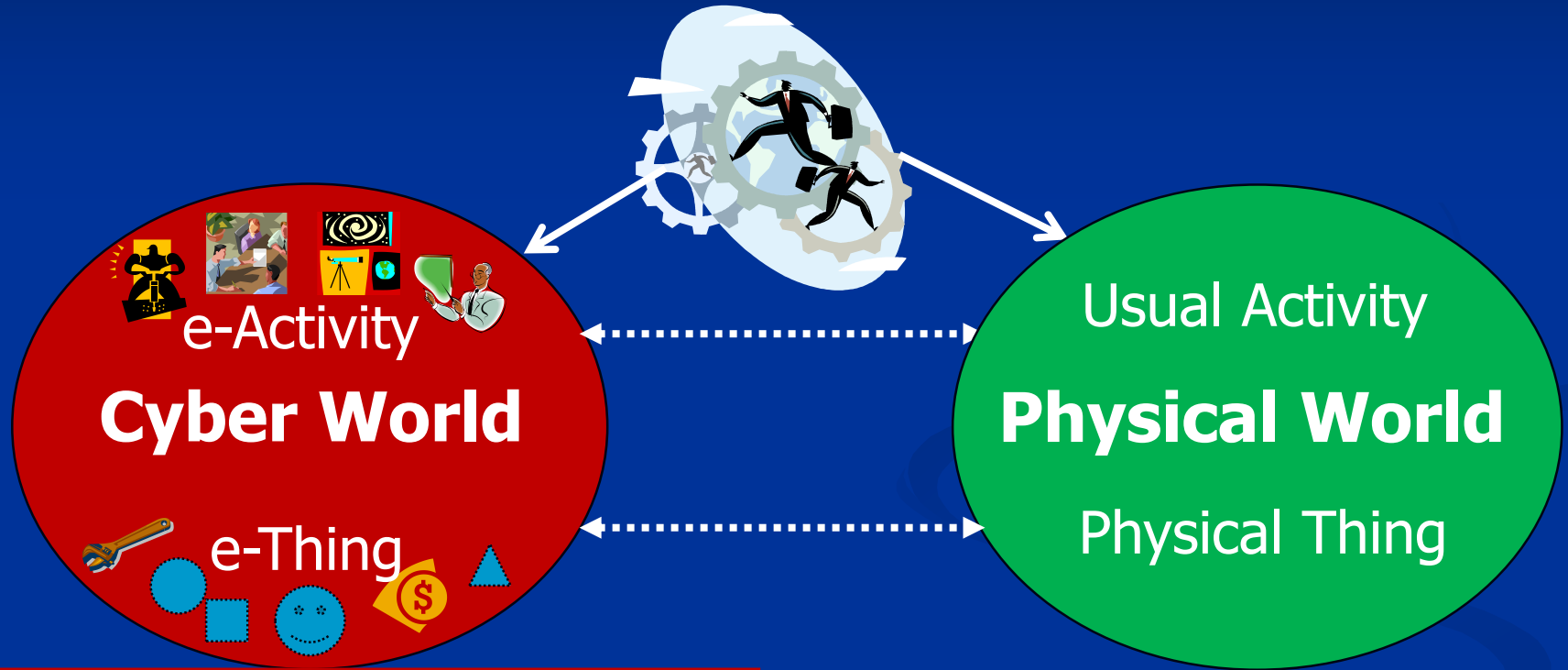
Various Things! → Many **IoX!**

What Kinds of Things in **IoT?**



# e-Thing in Digital/Cyber World

e-Things: digital things on cyber space in Cyber World



Web, WbS, SmW, Grid, P2P, XaaS, Cloud

Computers/Networks/Internet

**Cyber Space**

# u-Things → Physical Things with AEB

## ◆ Two Fundamental Technology Trends

- Continuing miniaturization of devices (Moore's law, new material, nanotech., ...)
- Available interconnections by ubiquitous/pervasive wired and wireless networks

**u-Things: Physical things** with some kind of **Attachment, Embedment, Blending (iThings)** (**AEB**) of computers, sensors, tags, networks, and/or other devices

*By J. Ma, "Smart u-Things: Challenging Real World Complexity", 2005*





# u-Things in Physical/Real World

u-Things: on the physical space in physical-digital form

IoT → Not Anything → Special Objects

IoT → u-Things in Physical World

**Cyber World**



e-Thing



**Physical World**

u-Thing

WbS, SmW, Grid, P2P, XaaS, Cloud

UC, ID, Context, Emb. Sys., Cloud, ...

Computers & Networks/Internet

**Cyber Space**

Sensor/M/NEMS, Comps & Per. Nets

**Physical Space**

# The Origination of IoT

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- The term “Internet of things” was first coined by the former Auto-ID Center, founded in 1999, based at the time at MIT. (*Kevin Ashton and David L. Brock*) → *RFID-based EPC* → *Only term!*
- (Sean Dodson, 2003) "IoT" can be expressed as the building of a **global infrastructure for RFID tags**.
  - @ You could think of it as a wireless layer on top of the internet where millions of things from razor blades to euro banknotes to car tyres are constantly being tracked and accounted for.
  - @ A network ... is for computers to identify "any object anywhere in the world instantly".
  - @ Put a tag - a microchip with an antenna - on a can of Coke or a car axle, and suddenly a computer can 'see' it.

# Formal Introduction of IoT

“We are heading into a new era of ubiquity, where the users of the Internet will be counted in billions, and where humans may become the minority as generators and receivers of traffic. Changes brought about by the Internet will be dwarfed by those prompted by the ***networking of everyday objects***” – UN report, 2005

*Internet of Things will connect the world's objects in both a sensory and intelligent manner through combining technological developments in:*

- *item identification ("tagging things")*
- *sensors and wireless sensor networks ("feeling things")*
- *embedded systems ("thinking things")*
- *nanotechnology ("shrinking things").*

*The ITU also identified as main challenges for the IOT :*

- *Standardization and Harmonization*
- *Privacy and Social and Ethical aspects.*



# Other Definitions of IoT

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- The Internet of things, also known as the Internet of objects, refers to the networked interconnection of everyday objects. It is described as a self-configuring wireless network of sensors whose purpose would be to interconnect all things.

*From Wikipedia*

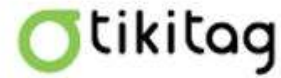
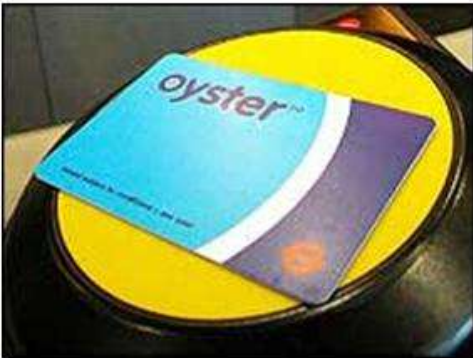
- (IoT is) a network of interconnected computers to a network of interconnected objects, from books to cars, from electrical appliances to food, and thus create an 'Internet of things'. These objects will sometimes have their own Internet Protocol addresses, be embedded in complex systems and use sensors to obtain information from their environment and/or use actuators to interact with it.

*From Internet of Things — An action plan for Europe (2009)*

- "Internet of Things" to refer to the general idea of things, especially everyday objects, that are readable, recognizable, locatable, addressable, and/or controllable via the Internet—whether via RFID, wireless LAN, wide-area network, or other means.

*From SRI Consulting Business Intelligence*

# Examples of Things in IoT





# Ubiquitous Connection of All Things



# Internet of Everything

The  
Economist

APRIL 28TH–MAY 4TH 2007

www.economist.com

Meet Britain's next prime minister

Will Africa ever get it right?

In praise of Yeltsin

The world's biggest banking battle

Australia's water crisis

## When everything connects

A 14-page special report on the coming wireless revolution



“... A myriad of hitherto separate objects are becoming connected to networks, from televisions and cars to industrial machinery and farmland....”

“... In years to come, wireless communications will increasingly become part of the fabric of everyday life... in 15 or 20 years' time, the network will have to accommodate a trillion devices...”



# Videos About IoT

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[An Introduction of Internet of Things from IBM](#)

[IOT will change everything from Cisco \(30 videos\)](#)

[Internet of Things by Dr. John Barrett at TEDxCIT](#)

[Harnessing the Internet of Things by Steve Lucas](#)

[Freescale's IoT Applications](#)

# Identification of a Thing

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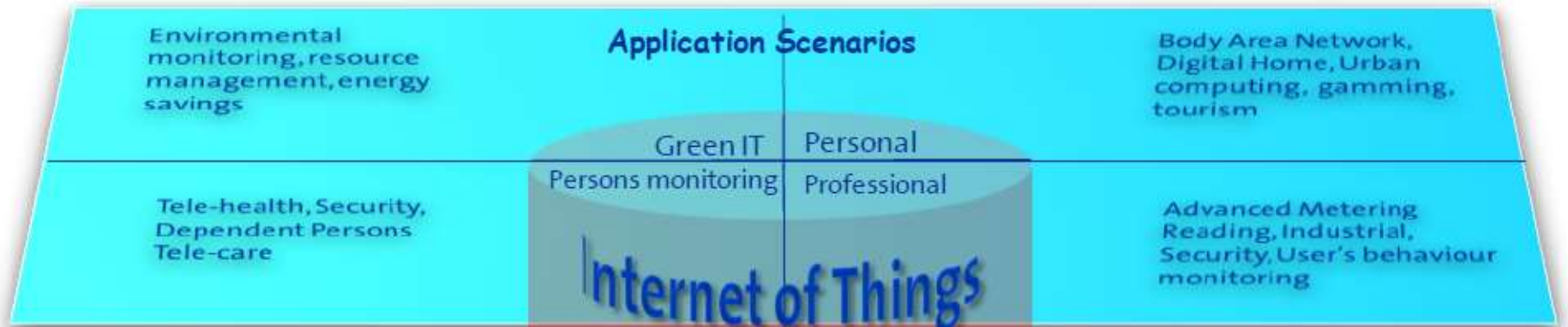
- What is a thing?
  - We distinguish two classes of things
    - Things that are computers including smart phones equipped with communication interfaces.
    - Things that are not computers, but who are associated with computers equipped with communication interfaces.
- What is the identifier of a thing?
  - They are several proposals:
    - A serial number, such as an EPC code.
    - An IP address, MAC address of Wifi, BlueTooth, SIM card code
    - Other, for example a fix hash value, or ad-hoc naming scheme.
- Authentication
  - Is there a need/way to authenticate a thing?
  - In other words, is it possible and needed to prove the identity of a thing?

# Things Attributives in IoT (SINTEF)

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- “Things” would be competing with other “things” on resources, services and subject to selective pressures
- “Things” can create, manage and destroy other “things”
- “Things” can use services that act as interfaces to “things”
- “Things” respect the privacy, security and safety of other “things” or people with which they interact
- “Things” use protocols to communicate with each other and the infrastructure
- “Things” can negotiate, understand and adapt to their environment
- “Things” can extract patterns from the environment or to learn from other “things”
- “Things” are environmentally safe
- “Things” can take decisions through their reasoning capabilities

# IoT Platform and Applications



# Applications Empowered by IoT (*IISD*)

## Global Environmental Observation

- GIS systems
  - Atmospheric
  - Vegetation / Ground Water
  - Surface / Water Temperature
- GHG Tracking
  - Consumption metering
  - Atmospheric measurements
- Reporting Systems
  - Mash-ups / SOA / Web 2.0

## Global Action / Management Plans

- Early Warning Systems
  - Famine / Drought
  - Natural Disasters
- Environmental Mitigation
  - Carbon-trading
  - Conservation Planning
- International Agreements
  - Ratification
  - Implementation

Global

Observation

Implementation

## Local Environmental Observation

- Capacity building
  - Awareness of threats
  - Identifying impact
- Data Entry
  - Web 2.0 / Wiki data logs
- Appropriate Technology
  - SMS / Mobile Phone usage
  - Cultural adaptation

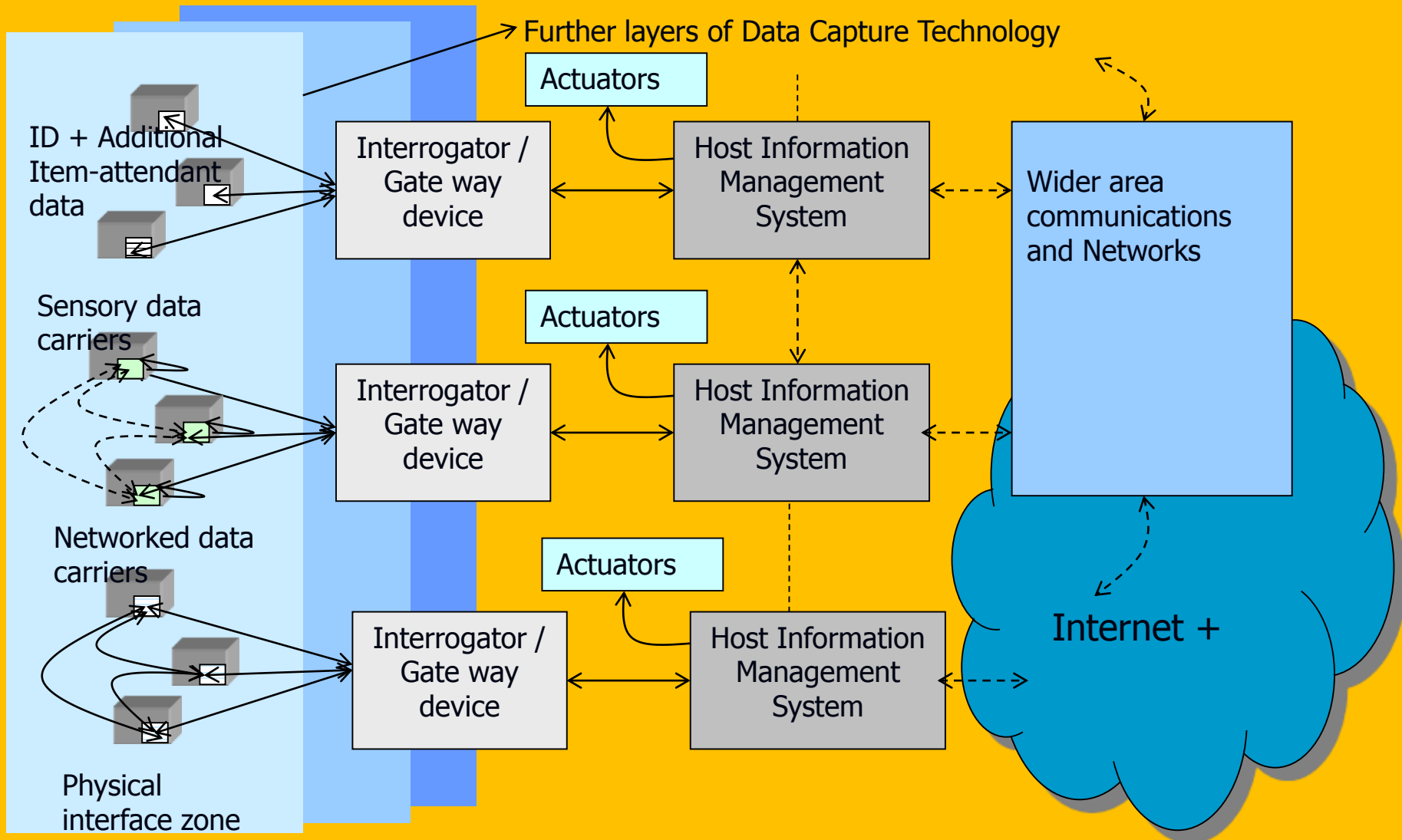
## Local Action / Management Plans

- Resource Management
  - Access / Allocation
  - Enforcement
  - Support and Funding
- Professional Development
- Response Planning
  - Early warning response
  - Conflict avoidance

Local

# One Conceptual Architecture of IoT

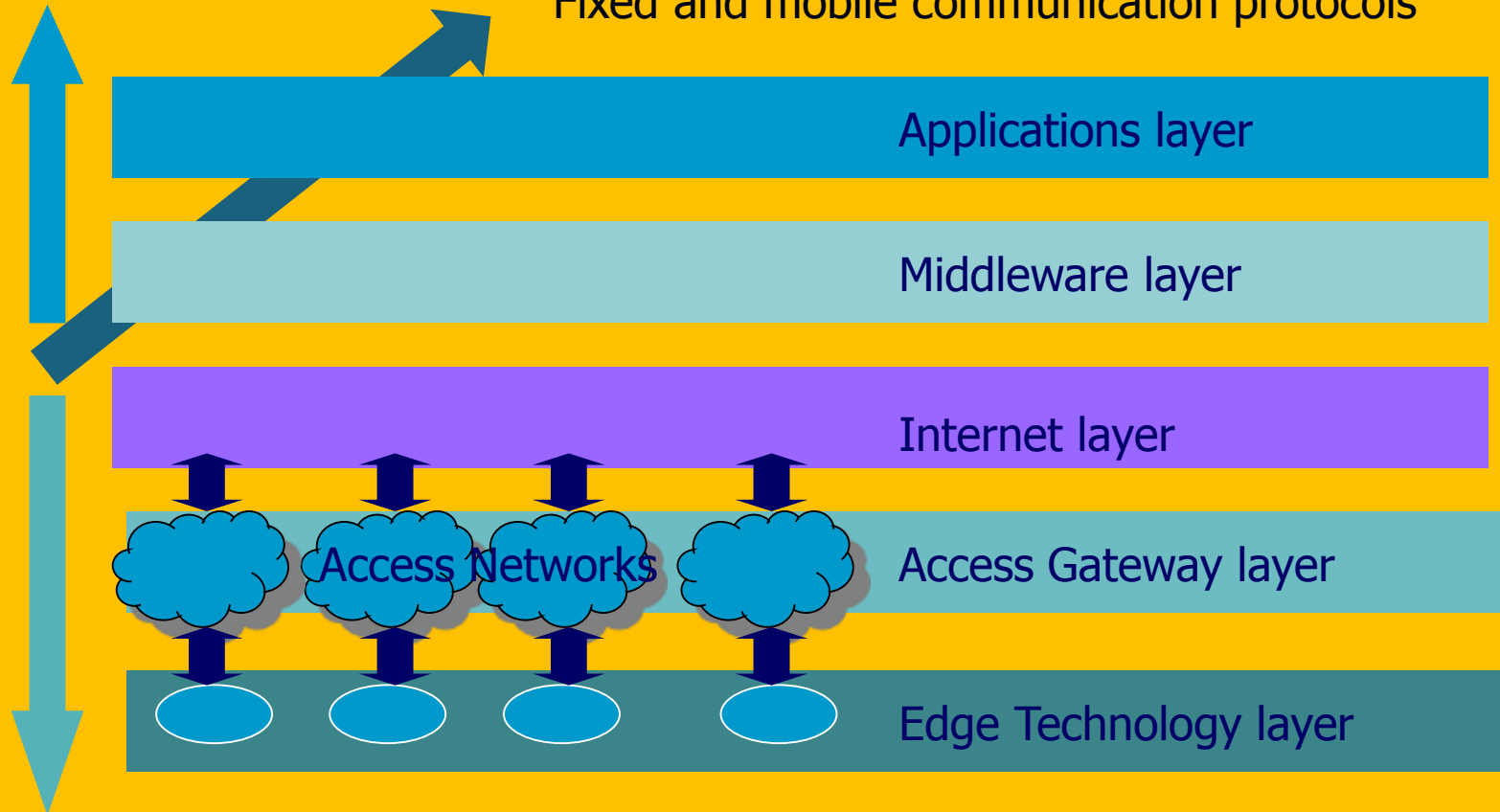
(GASAGRAS)



# A Layered Model of IoT (*GASAGRAS*)

Network-supported services

Fixed and mobile communication protocols



Edge-technology data capture and Networks

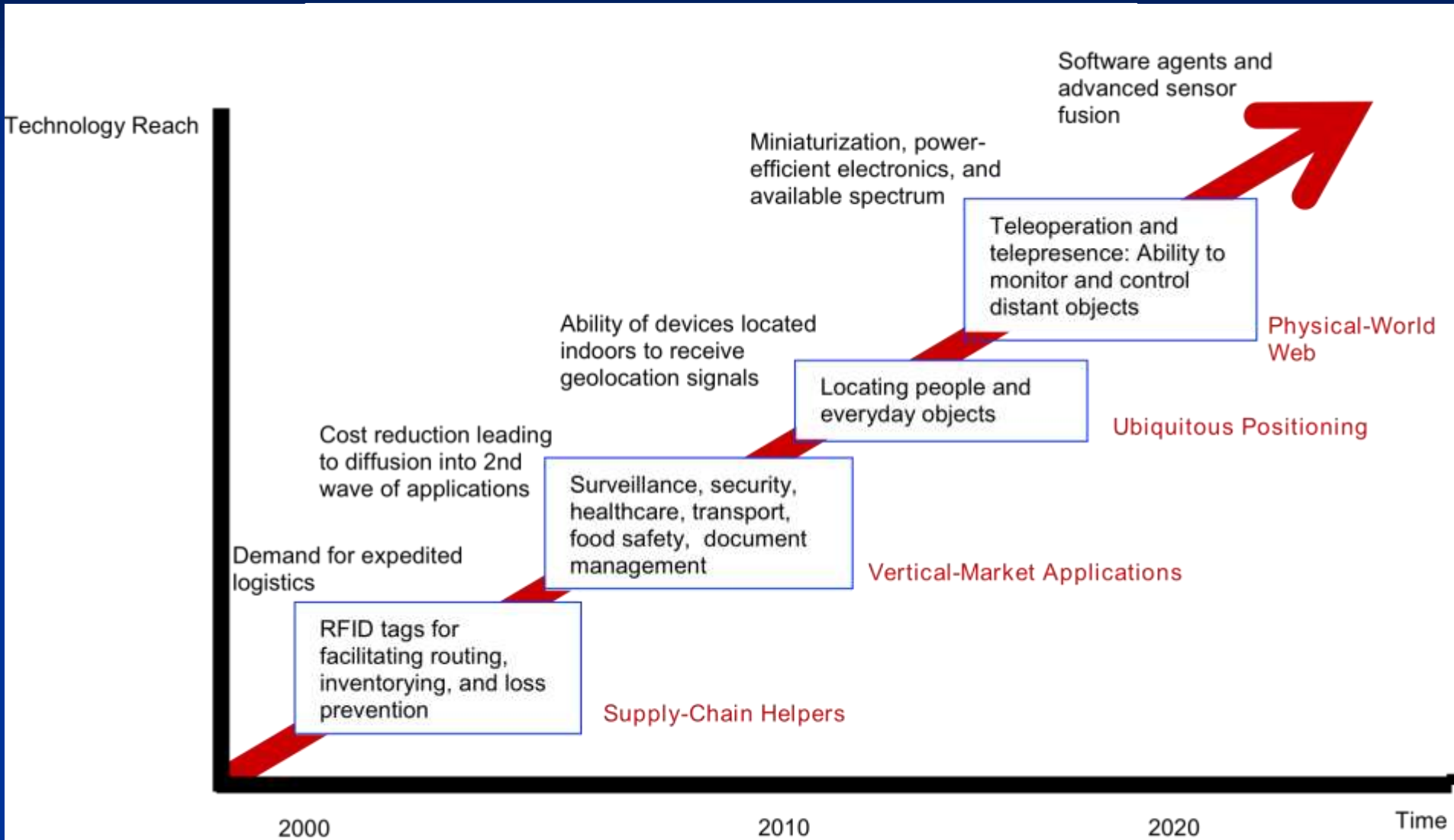
# Challenging Issues in IoT

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- How is a thing identification structured? (the object naming)
- Who assigns the identifier to a thing? (the assigning authority)
- How and where can additional information about that thing be retrieved, including its history? (the addressing mechanism and the information repository)
- How is information security/privacy/trust/safety ensured?
- Which stakeholders are accountable for each of the above questions, what is the accountability mechanism?
- Which ethical and legal framework applies to the different stakeholders?
- *What are uniform thing naming scheme, communication protocols between various things, thing's data collection, storage, query, management, processing, visualization, use, security, privacy, ....*



# Technological Roadmap of IoT



# What is Web of Things (WoT)?

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From Wikipedia

- The Web of Things is a vision inspired from the Internet of Things where everyday devices and objects, i.e. objects that contain an Embedded devices or computer, are connected by fully integrating them to the Web. Examples of smart devices and objects are Wireless Sensor Networks, Ambient devices, household appliances, etc.
- Unlike in the many systems that exist for the Internet of things, the Web of Things is about re-using the Web standards to connect the quickly expanding eco-system of Embedded devices built into everyday smart objects. Well-accepted and understood standards and blueprints (such as URI, HTTP, REST, RSS, etc.) are used to access the functionality of the smart objects.

# Technical Characteristics of WoT?

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From Wikipedia

- Uses HTTP as an application protocol rather than as a transport protocol as done in the world of WS-\* Web Services.
- Exposes the synchronous functionality of smart objects through a REST interface (also known as RESTful API) and more generally respects the blueprints of Resource Oriented Architectures.
- Exposes the asynchronous functionality (i.e. events) of smart objects through the use of largely accepted Web syndication standards such as Atom\_(standard) or server-push Web mechanisms such as Comet\_(programming).

These characteristics ensure the loose-coupling of services provided by the smart objects, furthermore they offer a uniform interface to access and build on the functionality of smart objects.

# Wisdom Web of Things (W2T)

Social World

Hyper World



Physical World



Cyber World

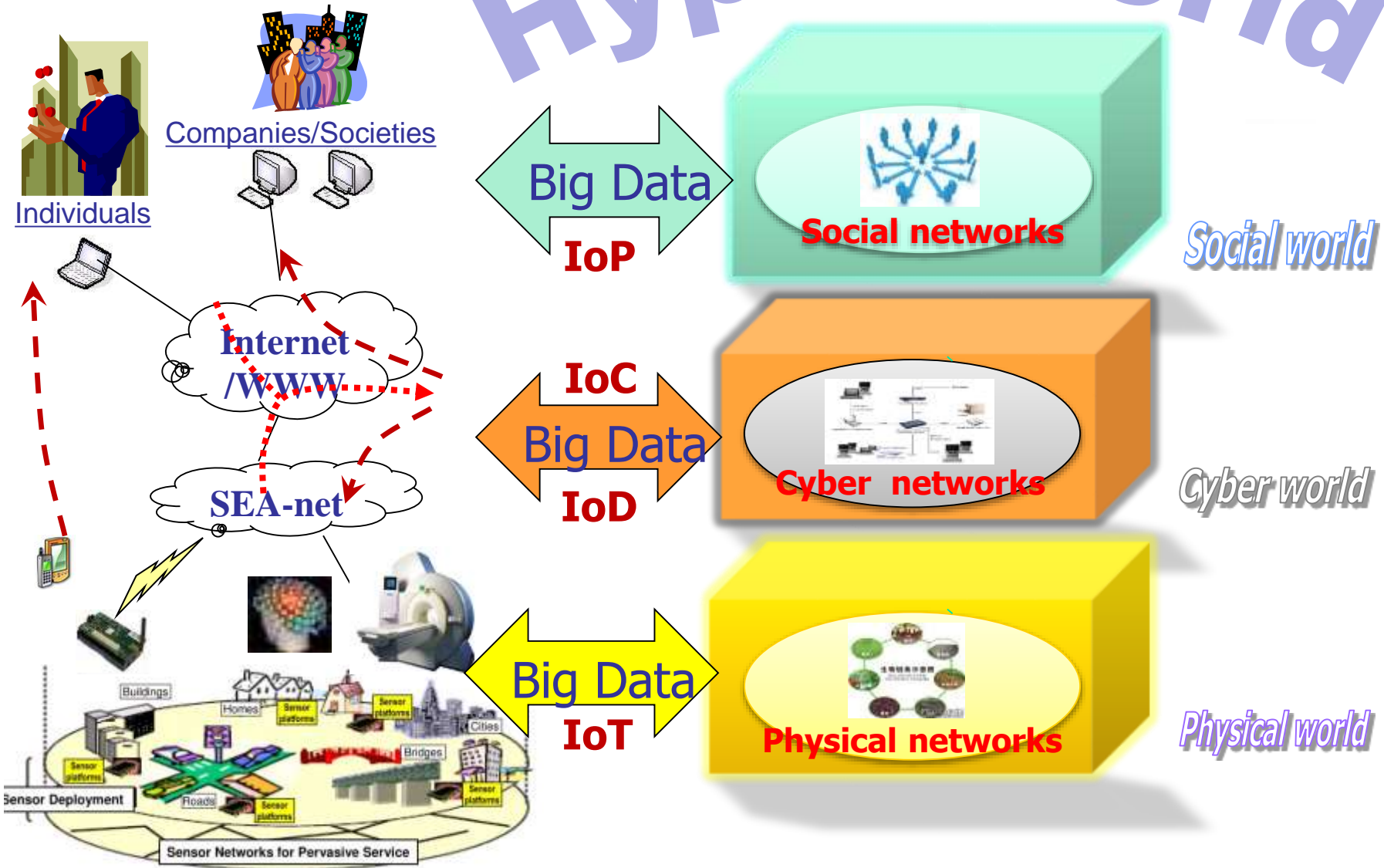
- The **Wisdom Web of Things (W2T)** is an extension of the **Wisdom Web** in the **hyper-world**.
- The “**Wisdom**” means that each of things in the **IoT /WoT** can be aware of both itself and others to provide the **right service for the right object at a right time and context**.
- To realize the **harmonious symbiosis** of **humans, computers** and **things** in the **hyper-world** by using the Intelligent Information Technology

**Research challenges and perspectives on wisdom web of things (W2T).**

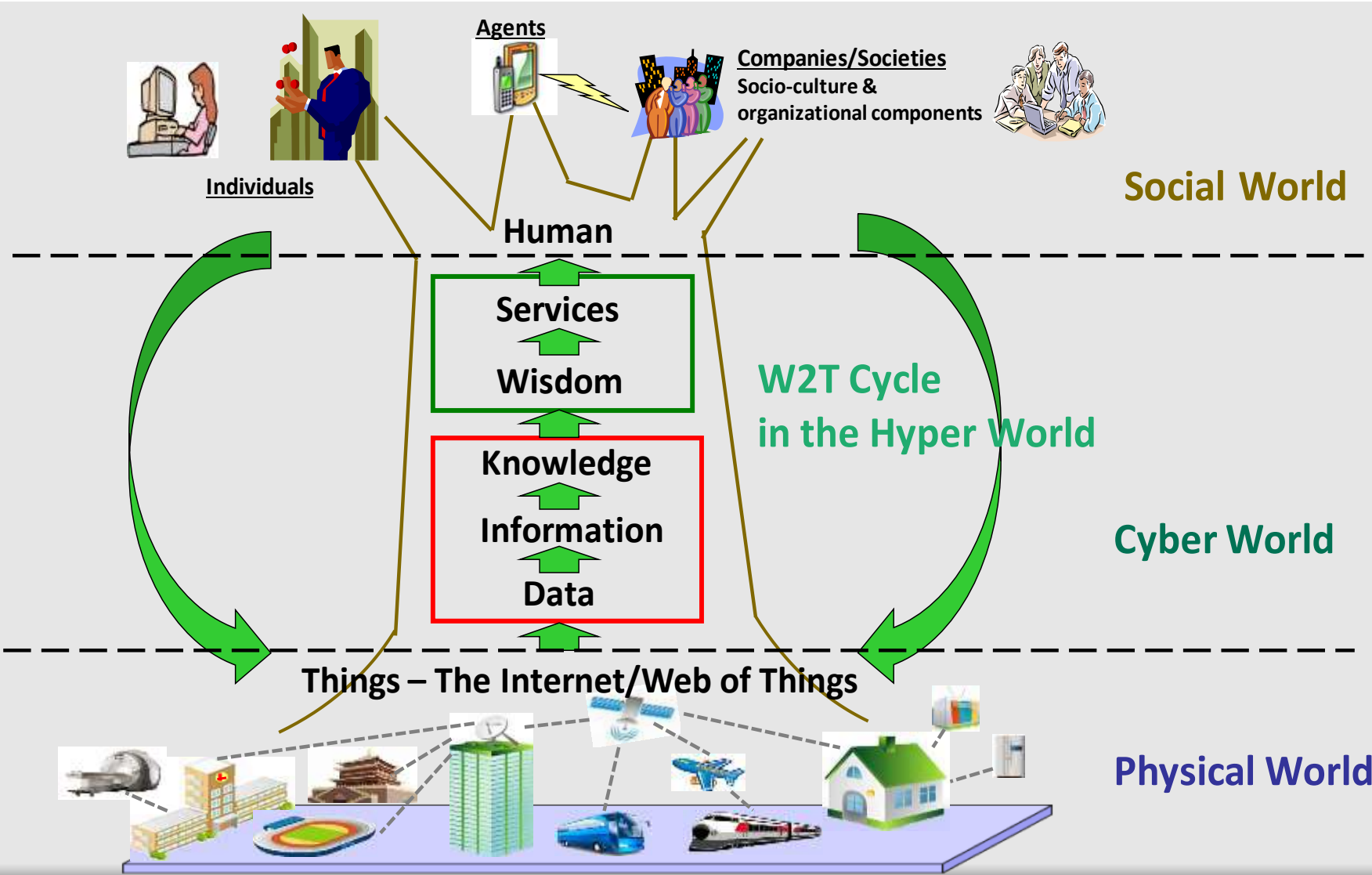
*Journal of Supercomputing, 2010.*

**Ning, Ma, Liu, Huang, Chen, Yao, Zhang**

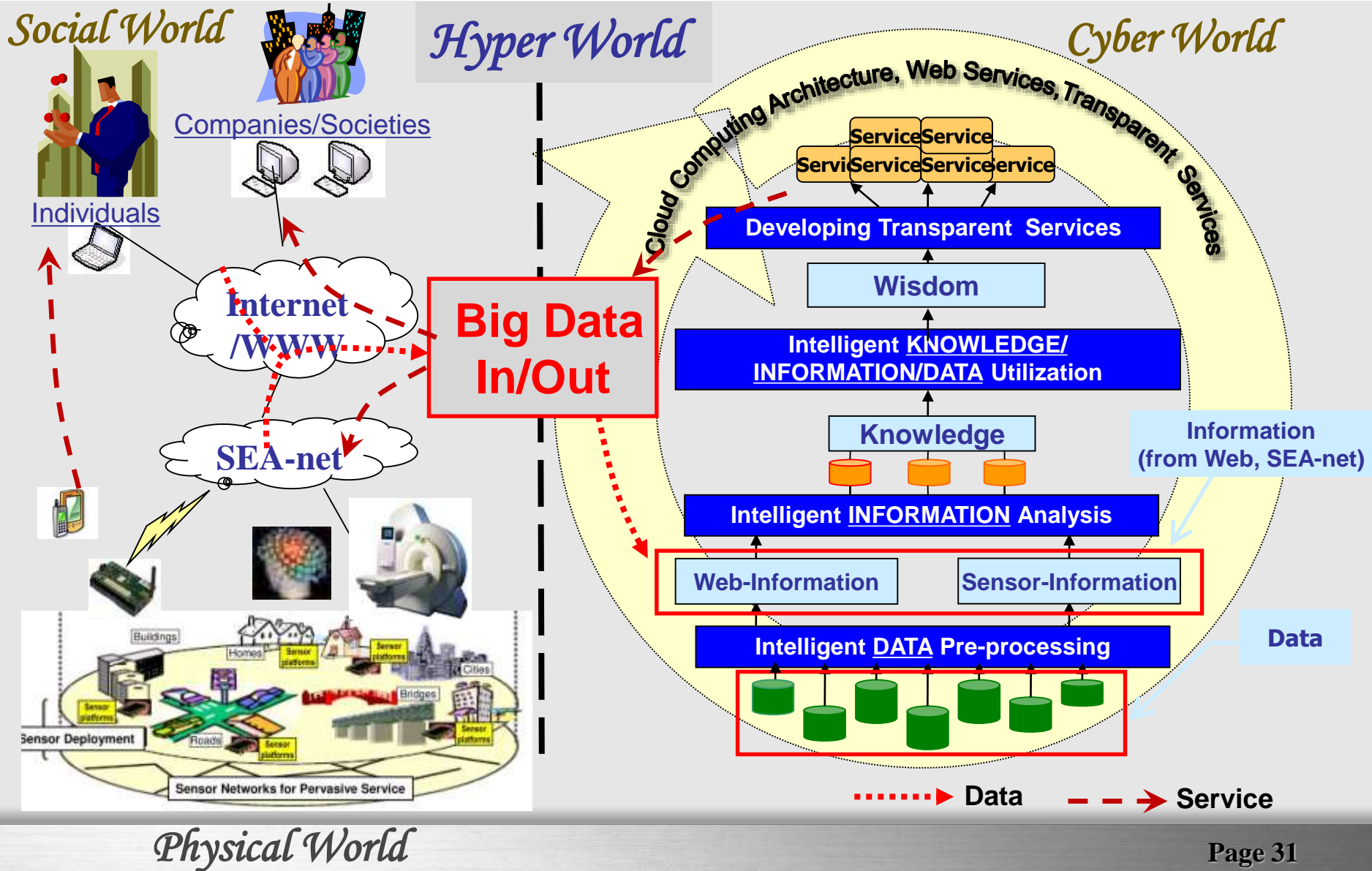
# Hyper World



# W2T Data Cycle

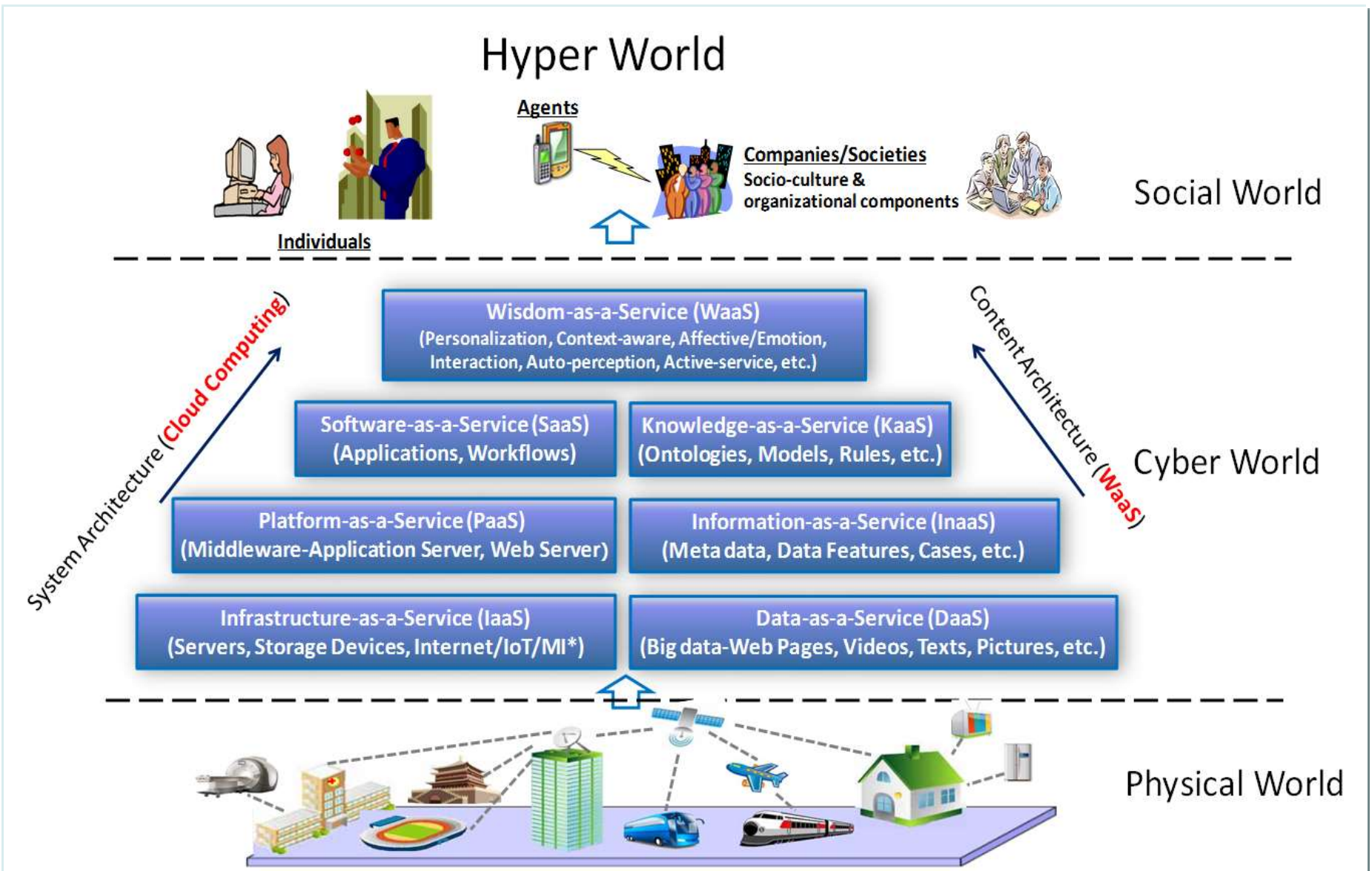


# W2T Intelligent Processing



# WaaS: Wisdom as a Service

## An Open Architecture for the W2T Cycle





# Homework

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- Browse the videos in previous slide, read the documents below and access the related websites to learn more about IoT & WoT, related concepts, visions, technologies, applications, etc.
- [Internet of Things — An action plan for Europe](#)
- [Background: The Internet of Things](#)
- [A Resource Oriented Architecture for the Web of Things](#)
- [Internet of Things – Wikipedia](#)
- [Web of Things – Wikipedia](#)
- [IoT 2010, Tokyo](#), [IEEE iThings 2013](#), [WF-IoT 2014](#)
- Others you like → Important to get materials from Web!!