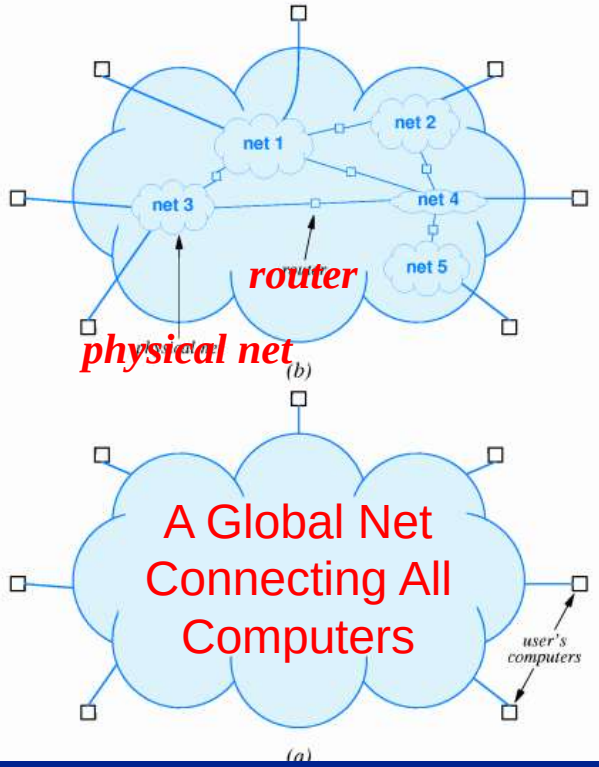
Lecture 11

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 co
  private, public, academic, business, and govern
  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**)

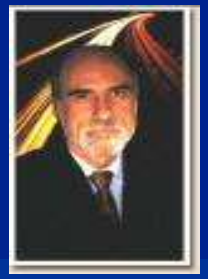
Leonard Kleinrock

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)

1st Web Graphical Browser

NCSA MOSAIC

⇩

Netscape

The Web → Internet of Documents (IoD)

Ted Nelson → Hypertext

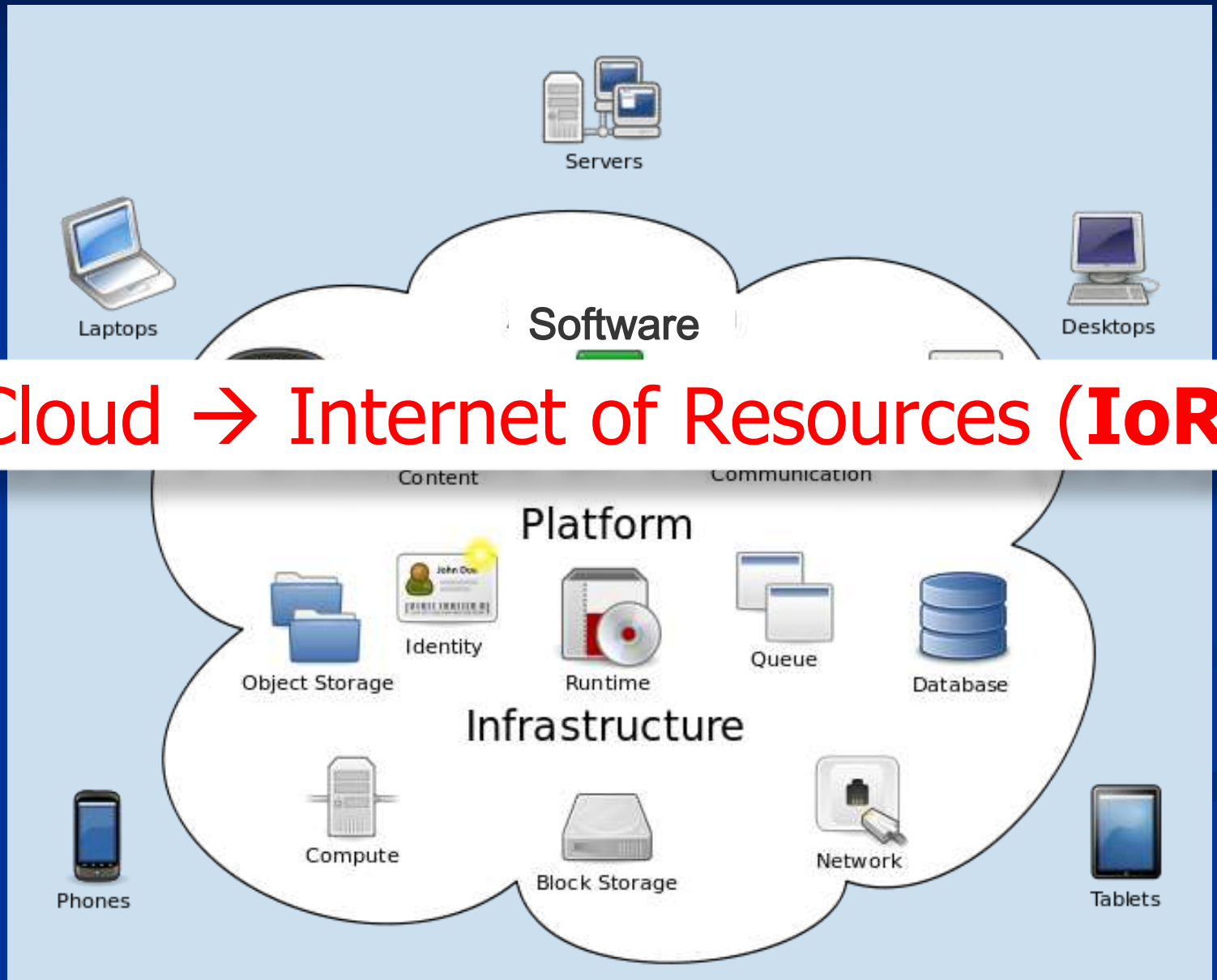
Tim Berners-Lee

1st Web Server

Mark Andreesen

How about Social Media/Web2.0?

How about Cloud Computing?



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

What are Things?

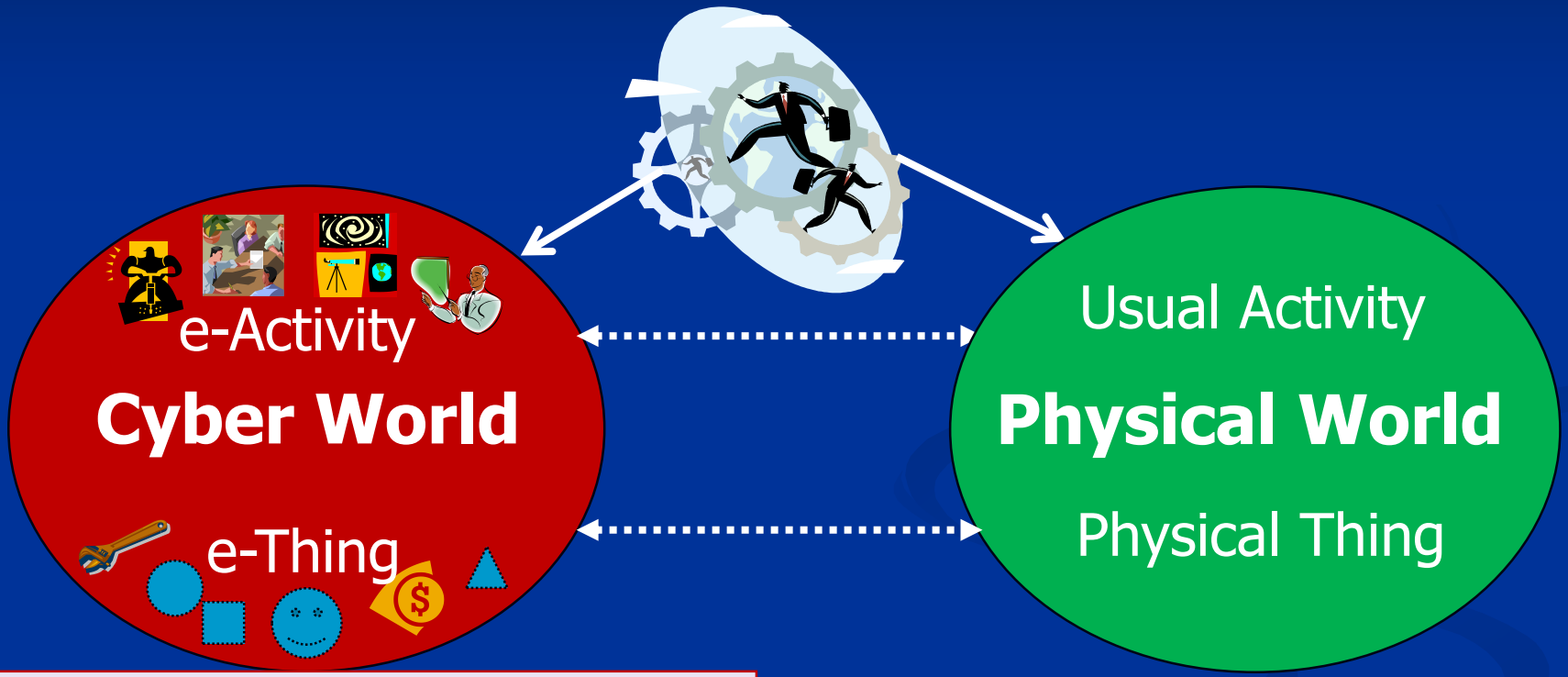
- **Thing** - An **object**, an entity, an idea, or a quality perceived, known, or thought to have its own existence, … *(dictionary)*
- **Object** – A tangible/visible **thing**; a person or thing seen as a focus or target for feelings, thought, etc.; a purpose/objective; ... *(dictionary)*
- Everyday 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

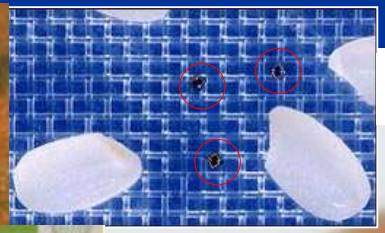
u-Things → Physical Things with AEB

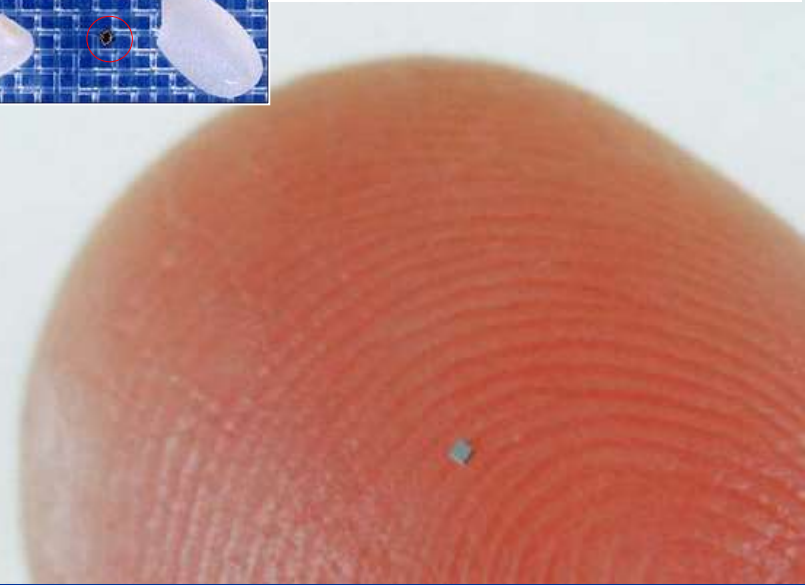
- Two Fundamental Technology Trends
  - Continuing miniaturization of devices (Moore's law, new material, nanotech., …)
  - Available interconnections by ubiquitous/pervasive wired and wireless networks

u-Things: **Physical things** with some kind of **A**ttachment, **E**mbedment, **B**lending (**AEB**) of computers, sensors, tags, networks, and/or other devices

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



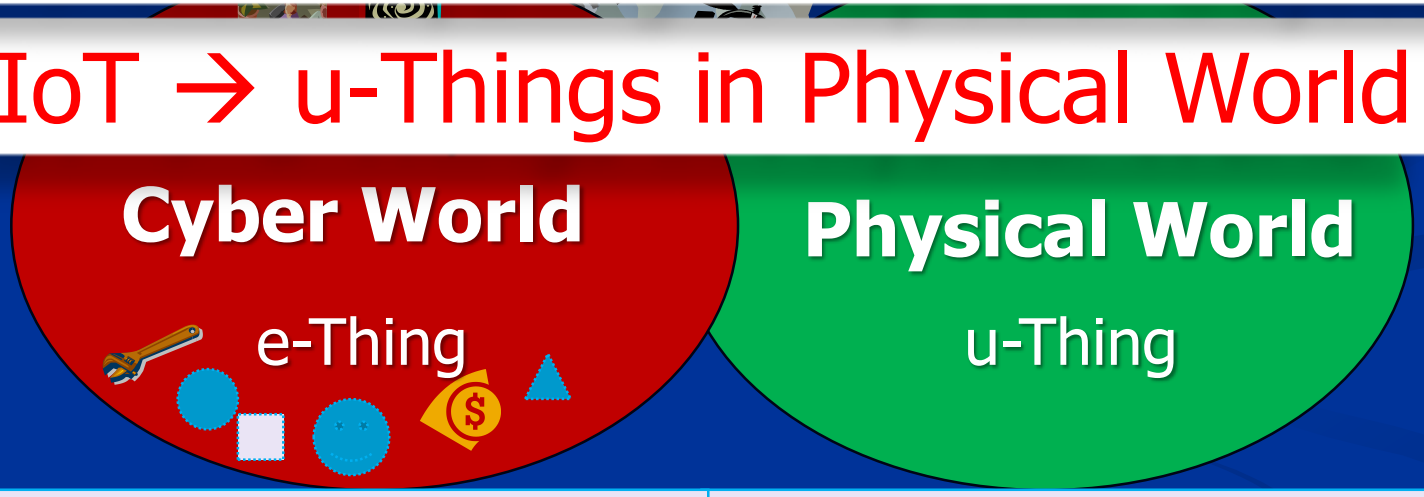
0.15x0.15 mm, Hitachi/06

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



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

- 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

- 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

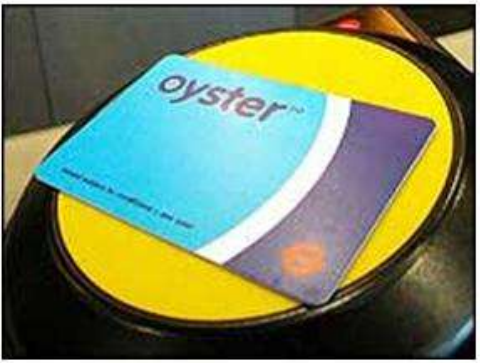
- (IoT is) a network of interconnected computers to a network of interconnected objects, from books to cars, from electrical appliances to food, and thus create an 'Internet of things'. These objects will sometimes have their own Internet Protocol addresses, be embedded in complex systems and use sensors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



tikitag

Ubiquitous Networks

Object-To-Object (O2O), Thing-To-Thing (T2T)

Many physical things are connected, can talk

全てのモノが繋がる世界 → 対話(通信)できる

Ubiquitous Connection of All Things

Internet of Everything

"... 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

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

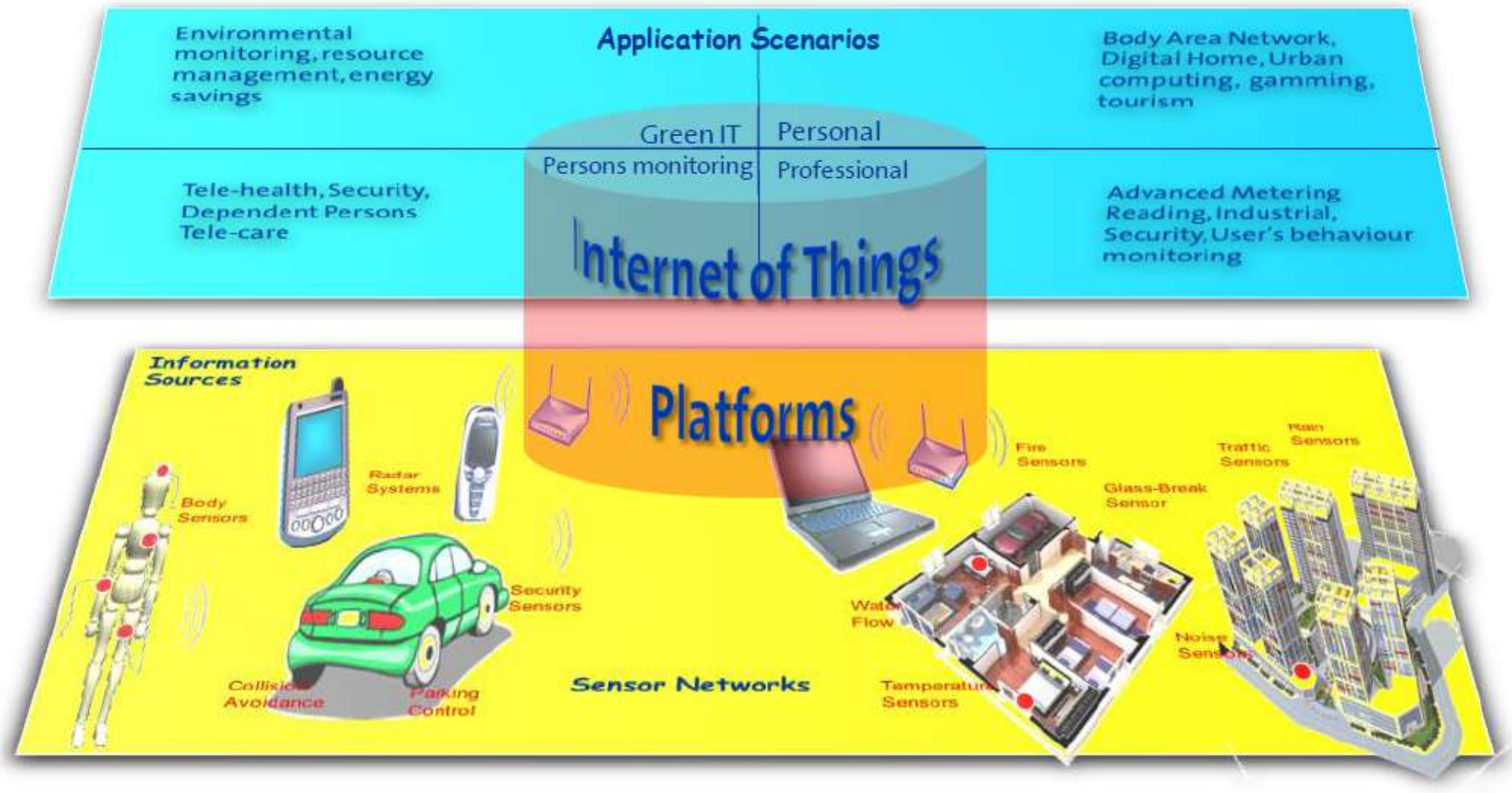
Identification of a Thing

- 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.
    - 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)

- “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



From CERP-IOT

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**

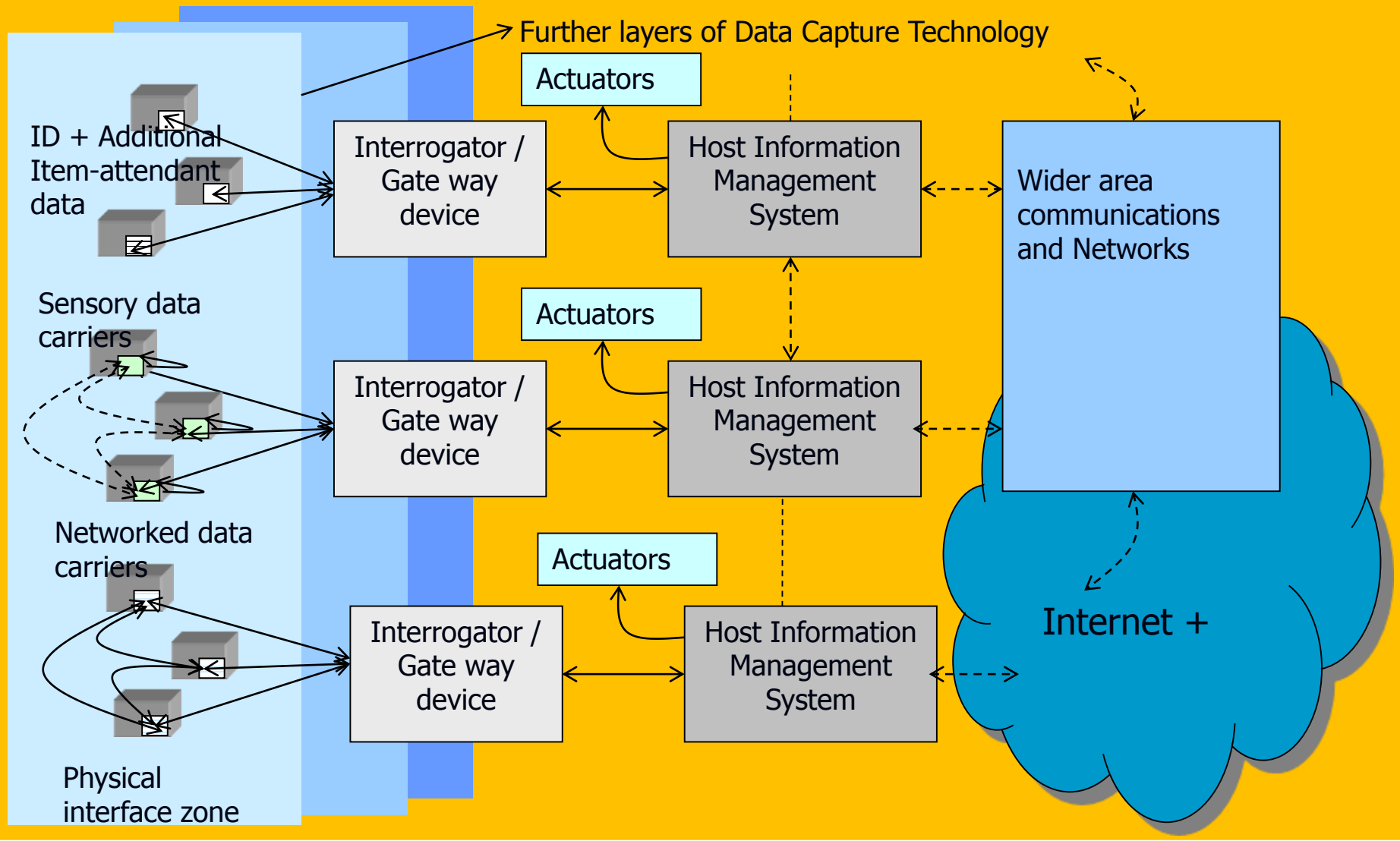
Local

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

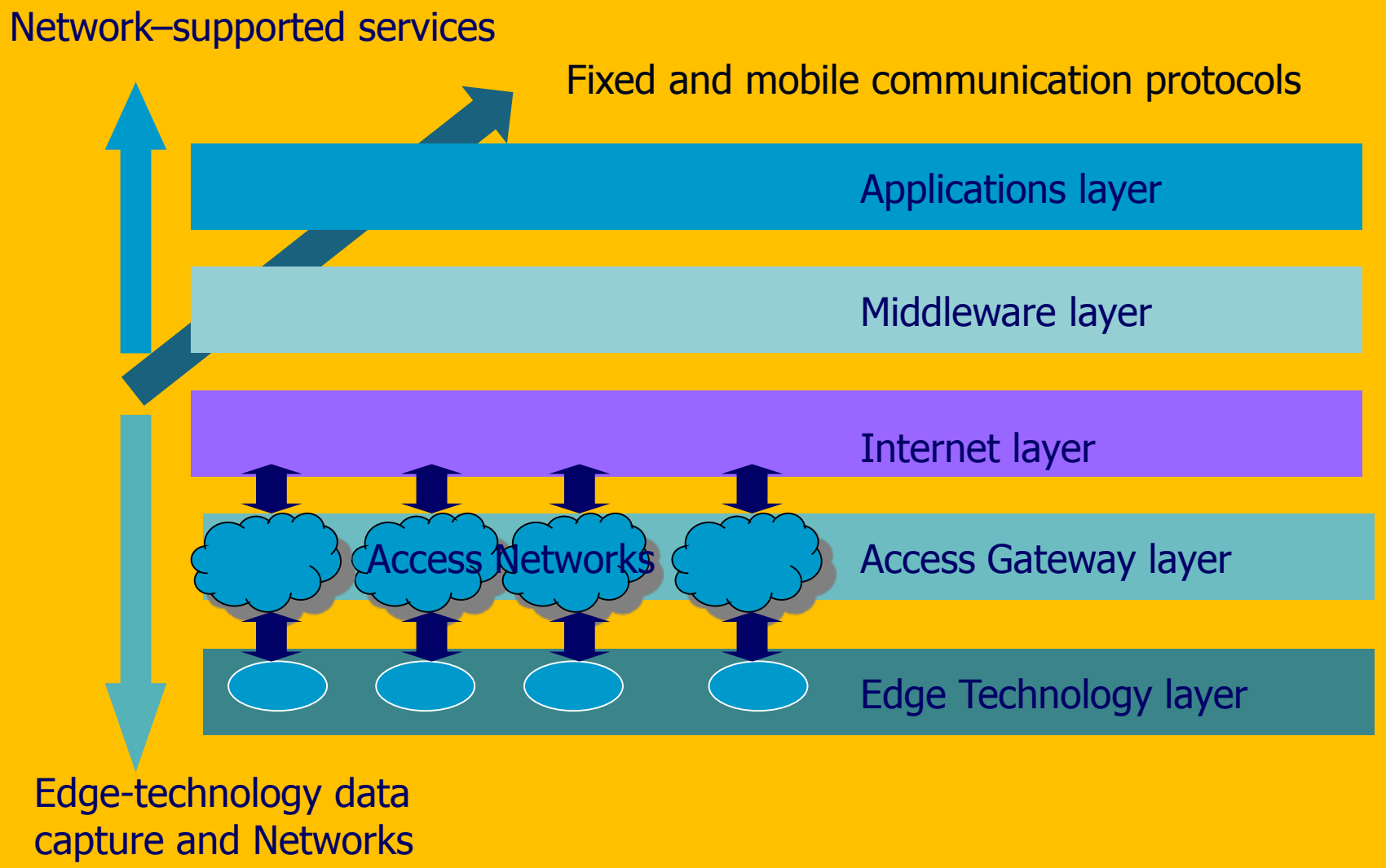
Local Action / Management Plans
- Resource Management
  - Access / Allocation
  - Enforcement
  - Support and Funding
- Professional Development
- Response Planning
  - Early warning response
  - Conflict avoidance

One Conceptual Architecture of IoT

(GASAGRAS)



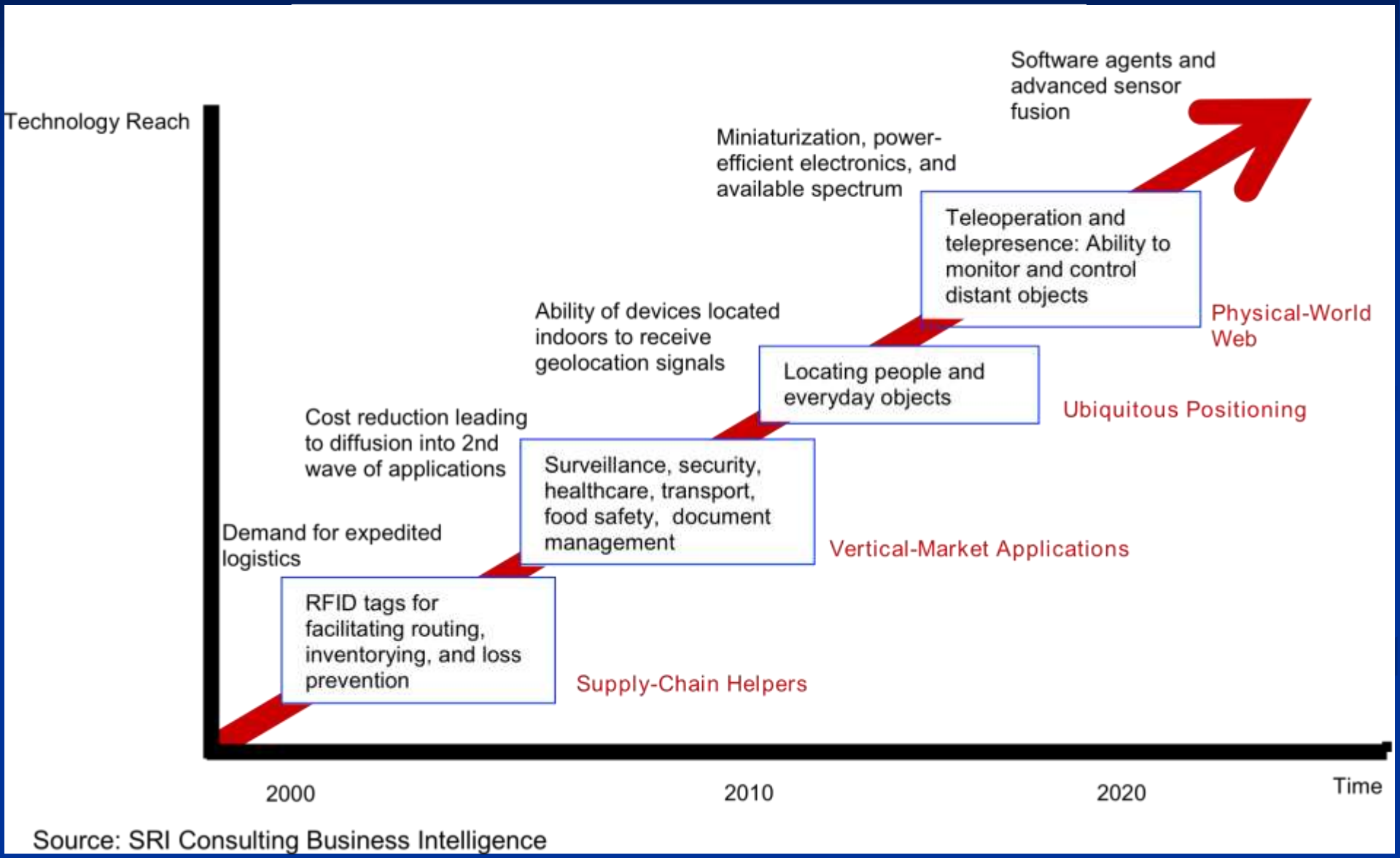
A Layered Model of IoT *(GASAGRAS)*



Challenging Issues in IoT

- 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



Source: SRI Consulting Business Intelligence

What is Web of Things (WoT)?

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 expending 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.

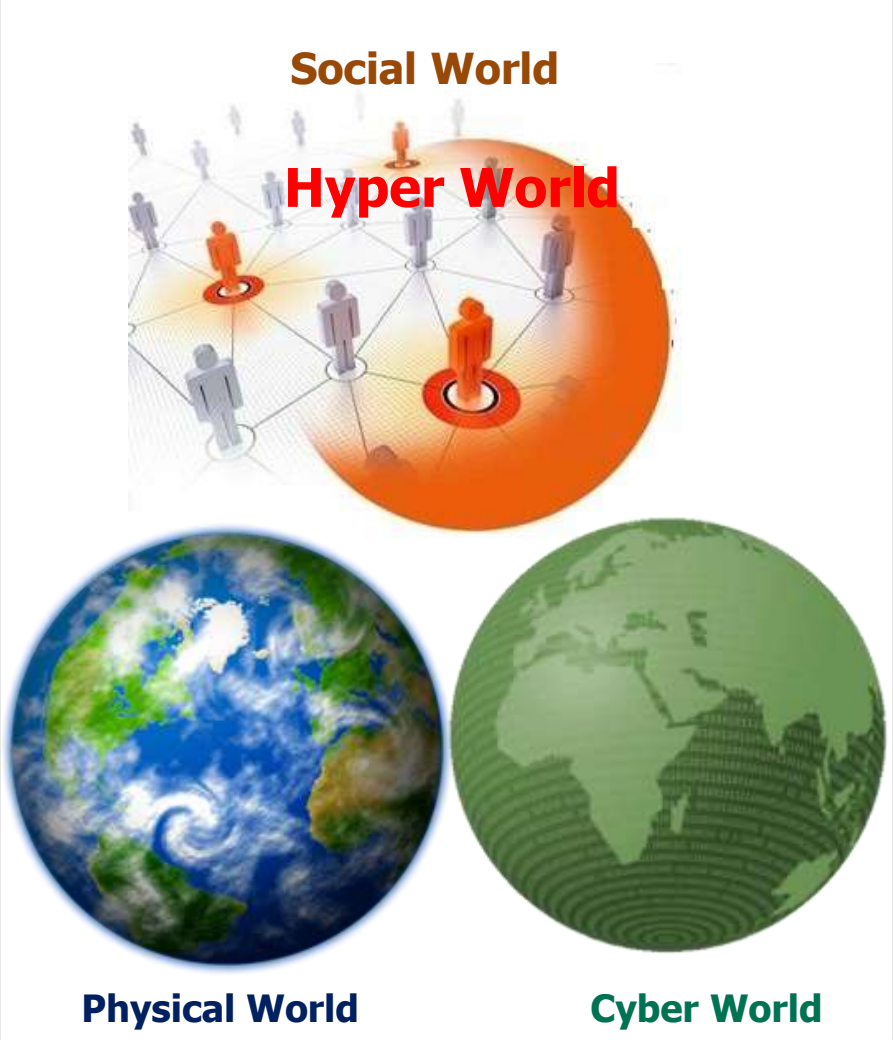
Technical Characteristics of WoT?

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.

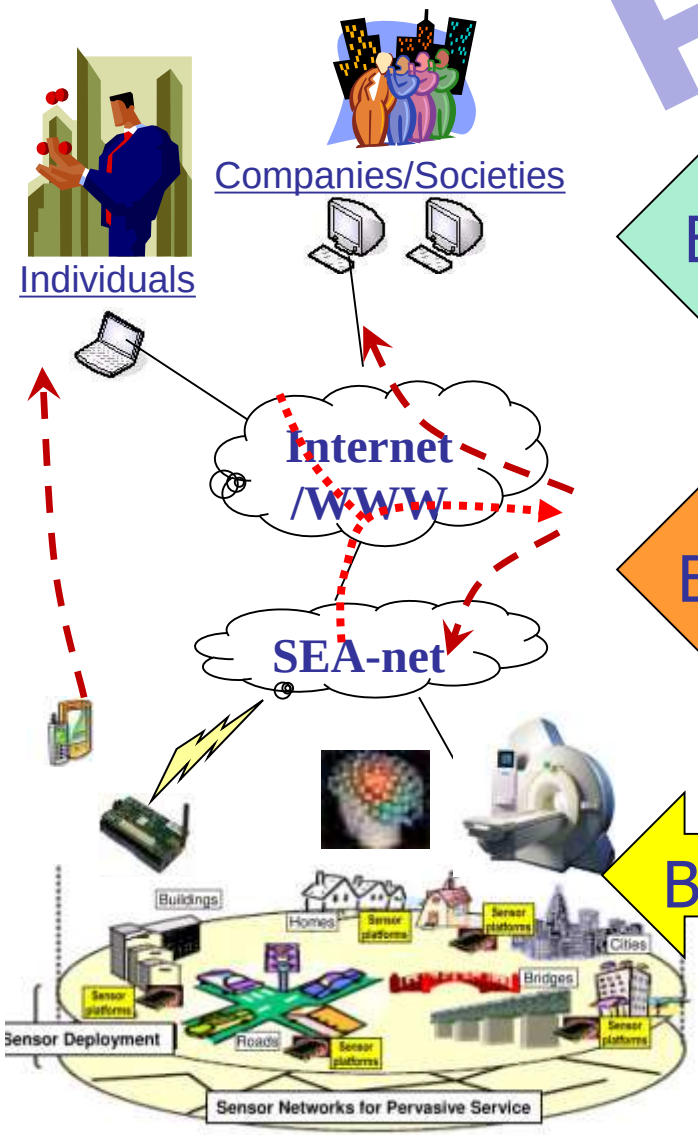
Wisdom Web of Things (W2T)



- 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

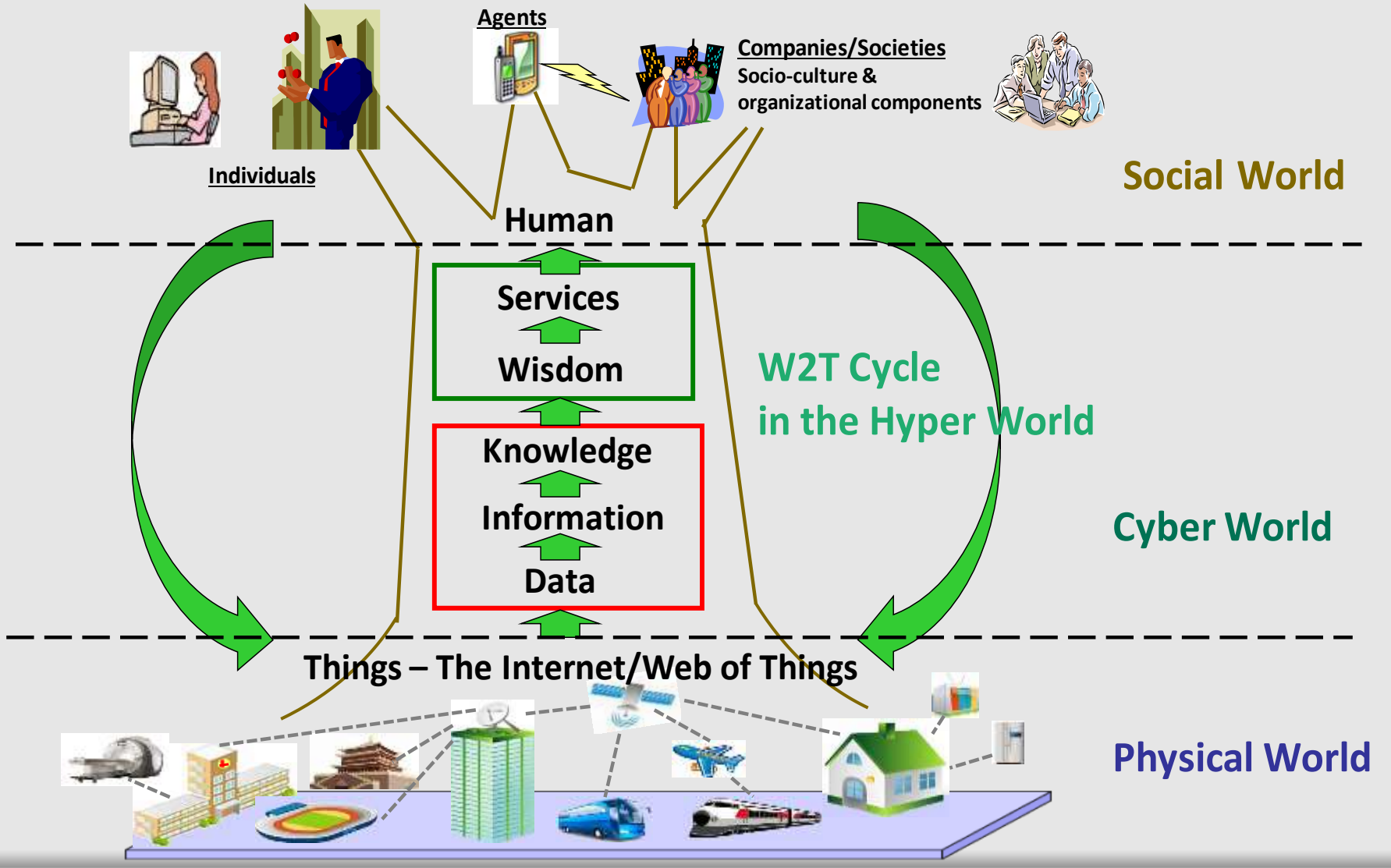


Big Data
IoP
Social networks
Social world

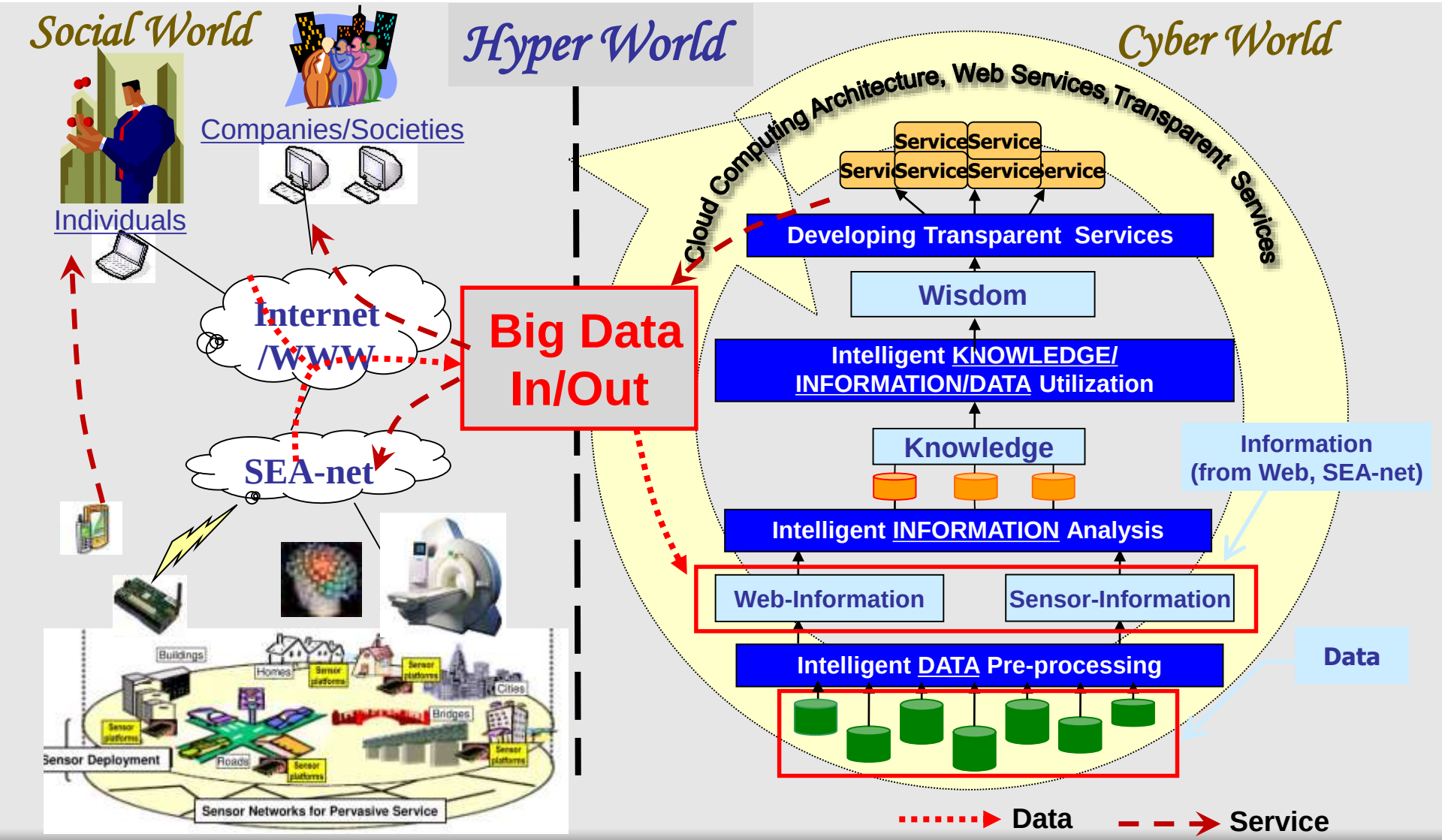
IoC
Big Data
IoD
Cyber networks
Cyber world

Big Data
IoT
Physical networks
Physical world

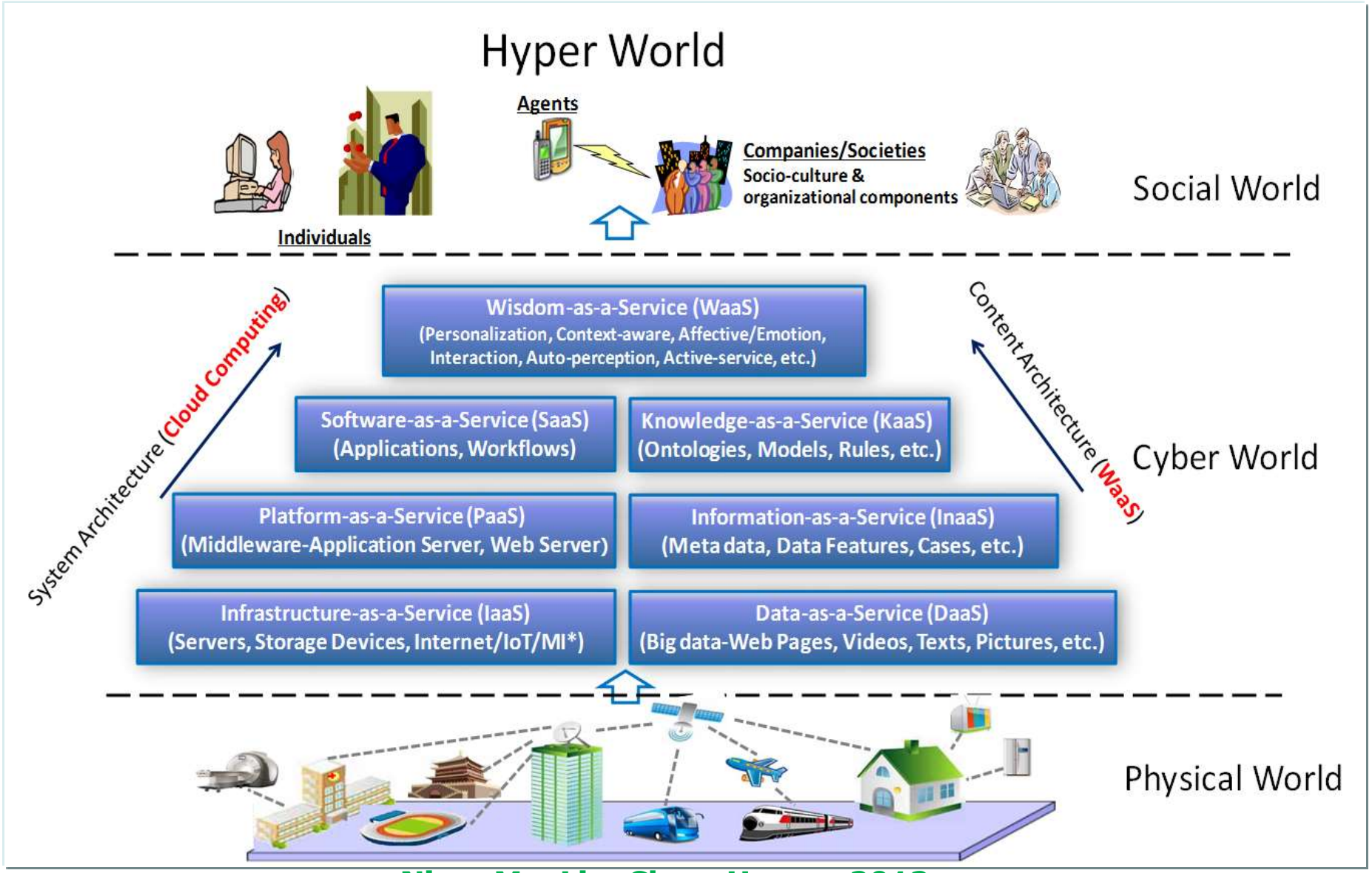
W2T Data Cycle



W2T Intelligent Processing



WaaS: Wisdom as a Service
An Open Architecture for the W2T Cycle



Ning, Ma, Liu, Chen, Huang, 2012

Homework

- 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!!