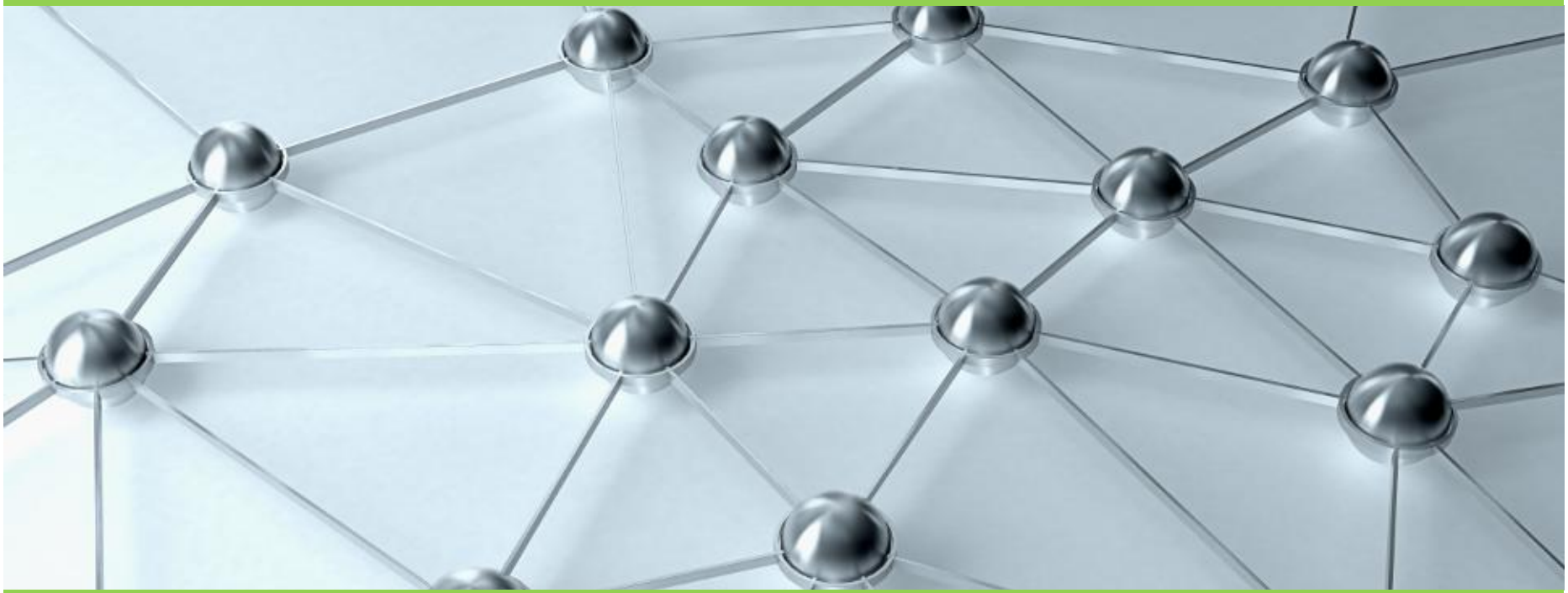


Two Novel Technologies Enabling IoT: Mobile Clouds and Visible Light Communications

Marcos Katz

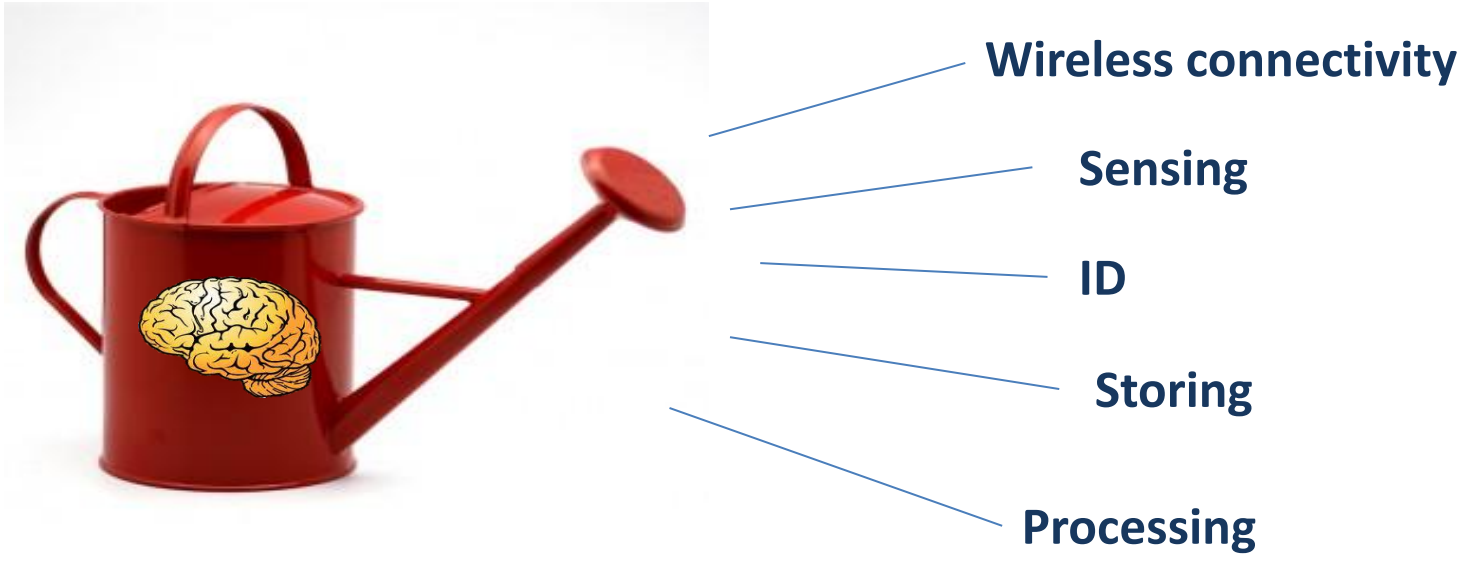
Centre for Wireless Communications

University of Oulu, Finland

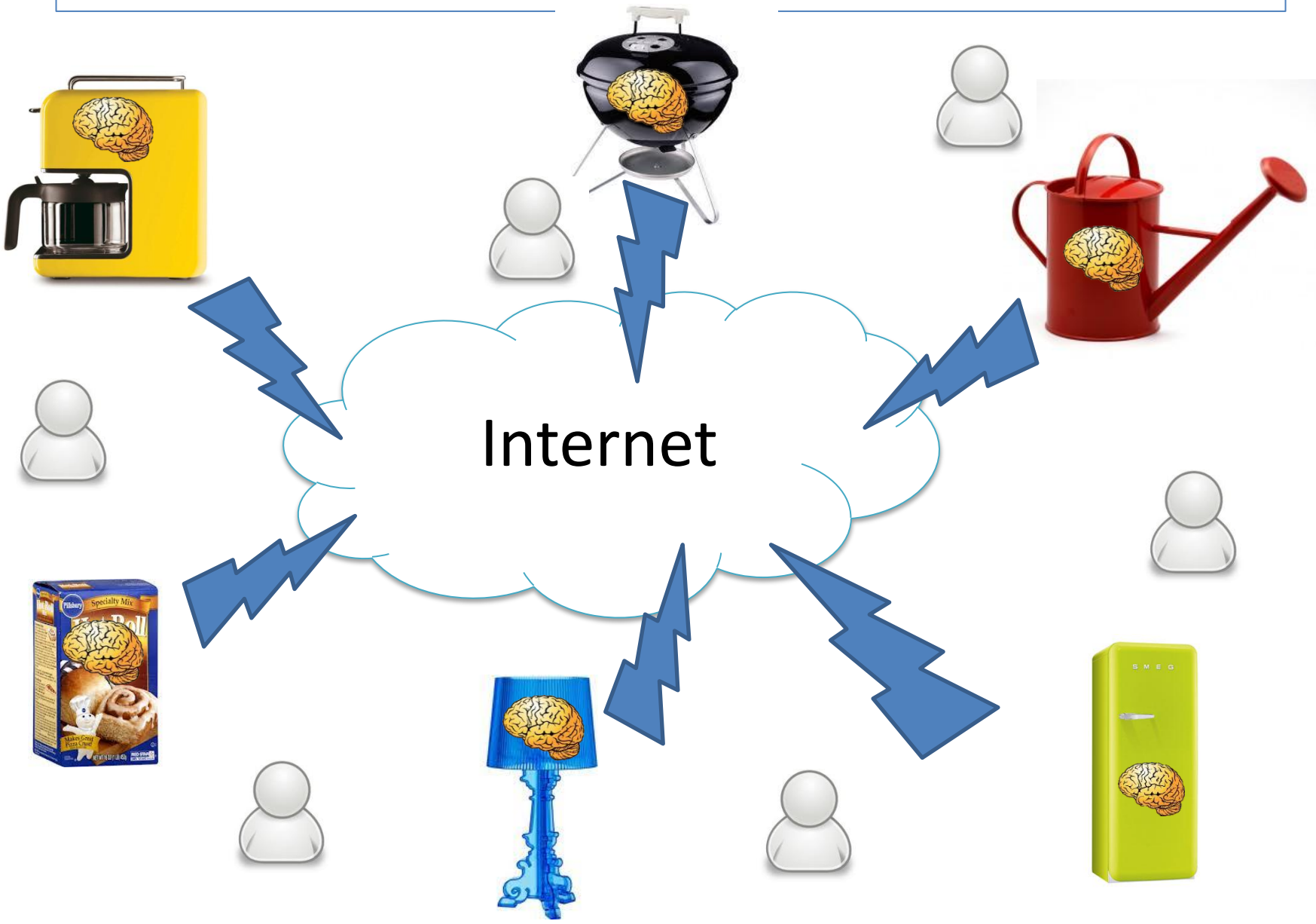
Introduction: Internet of Things (**IoT**)

- What is **IoT**?
  - No precise definition exists, numerous **visions** on IoT can be found...
- IoT is a vision of a **hyperconnected world** of **objects**, virtually **everything**, and **every thing**...
- **Objects/things**

  A) have some (limited) intelligence; **b)** can be networked



Introduction: Internet of Things (**IoT**)



Introduction: Internet of Things (**IoT**)

IoT?

Internet

Introduction: Internet of Things (**IoT**)

Characteristics:

- **Objects**
  - Heterogeneous, many, everywhere
  - Small, big, fixed, movable, moving
- **Intelligence on board**
  - Interact with the environment (sensing)
  - Connectivity (communications capabilities)
  - Identify uniquely the object and its conditions (ID)
  - Processing capabilities (CPU + memory)
  - Controllable (operations/settings are controllable)
- **Network**
  - Global interconnection

Introduction: Internet of Things (**IoT**)

- According to **WWRF** (Wireless World Research Forum), by year 2020 there will be **seven trillion** wireless devices serving **seven billion** people.

- Impact on virtually every aspect of modern life
  - Home
  - Work
  - Factories
  - Transportation
  - Logistics
  - Etc.

- Great impact on **quality of life** and **utilization of resources**

Introduction: Internet of Things (**IoT**)

- Many challenges:
- Our interest in the **wireless communications** aspect of IoT.

Some key questions:

- How to use efficiently the limited (battery) energy in the objects for providing wireless connectivity?
- How to avoid congesting networks (wireless and wired) with exploding amount of generated data?
- How to use more efficiently the available (and very scarce) spectrum?
- Role of humans (users) in IoT?

Some possible approaches to be considered

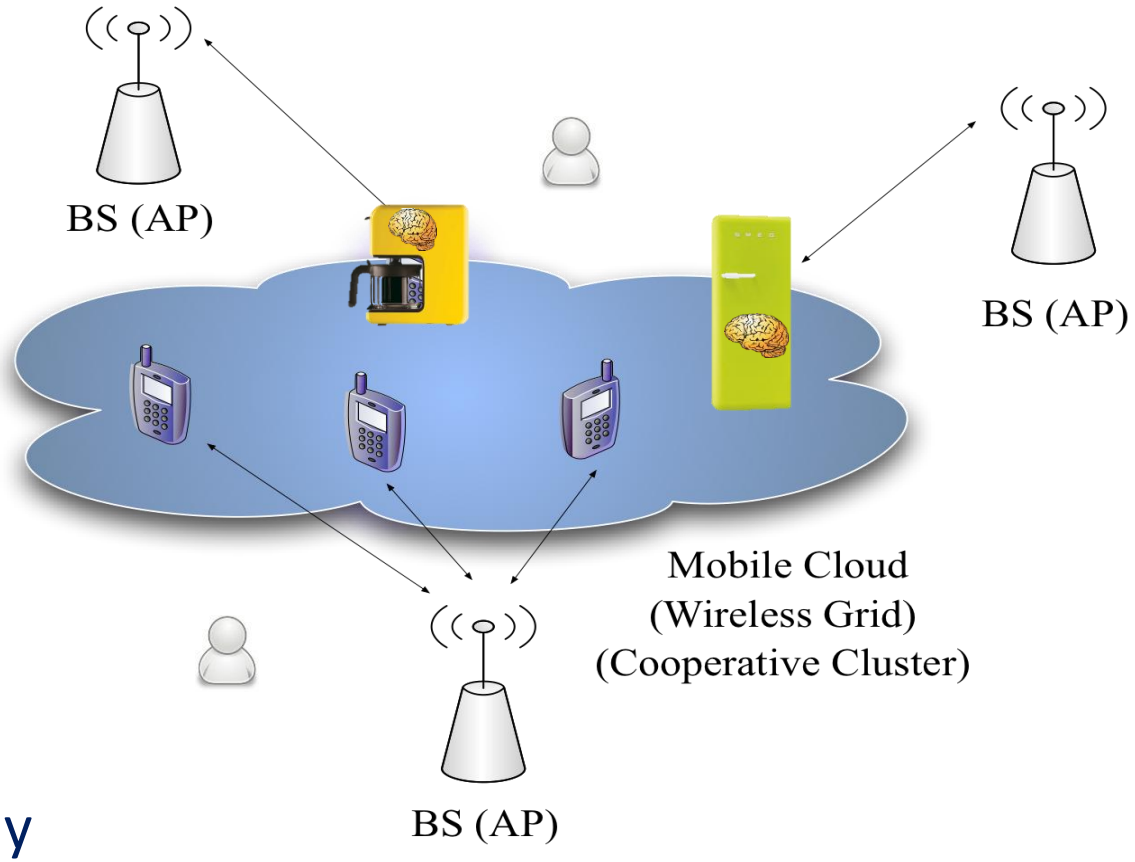
- Mobile clouds
- Visible Light Communications (VLC)

Mobile Clouds

Definitions: A mobile cloud as a **collaborative arrangement** between closely located wireless devices (e.g., through short-range links) which can also be connected to a cellular access simultaneously.

A mobile cloud is in general a **dynamic** and **opportunistic** network.

A mobile cloud is a very flexible platform for sharing, exchanging and moving resources efficiently



Mobile Clouds: Resources

- **Radio Resources**
  - Time, Space, Frequency (spectrum), Energy/Power
- **Built-in Active Resources**
  - Processing power (CPU, DSP), mass memory, batteries
- **Built-in Passive Resources**
  - **Sensors**: position, orientation, microphone, imaging devices (CCD), temperature, radiation, pollution, etc.
  - **Actuators**: loudspeakers, displays, etc.
- **Social Resources**
  - **Individual** behind (i.e., controlling) the mobile device and its behavior
  - **Groups** and their social strategy/behavior
- **Connectivity Resources**
  - Air interfaces onboard providing local and wide area connectivity
- **Apps Resources**
- **Data/information** (stored in or generated by wireless devices)

Mobile Clouds

What do mobile clouds offer?

- Better **performance** than non-cooperative approaches (e.g., data rates, QoS, reliability)

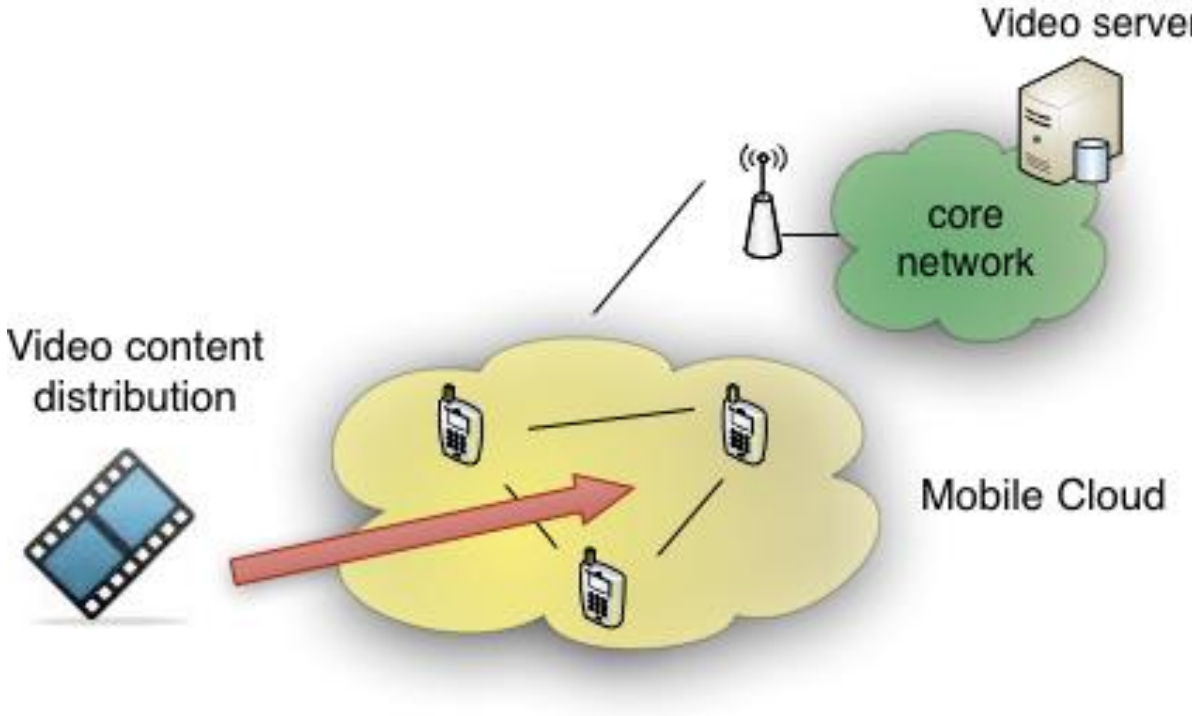
- **Resources** can be used more **efficiently** (e.g., energy, spectrum, etc.)

- Potential for **novel services and applications** exploiting distributed resources

Possible Applications of Mobile Clouds

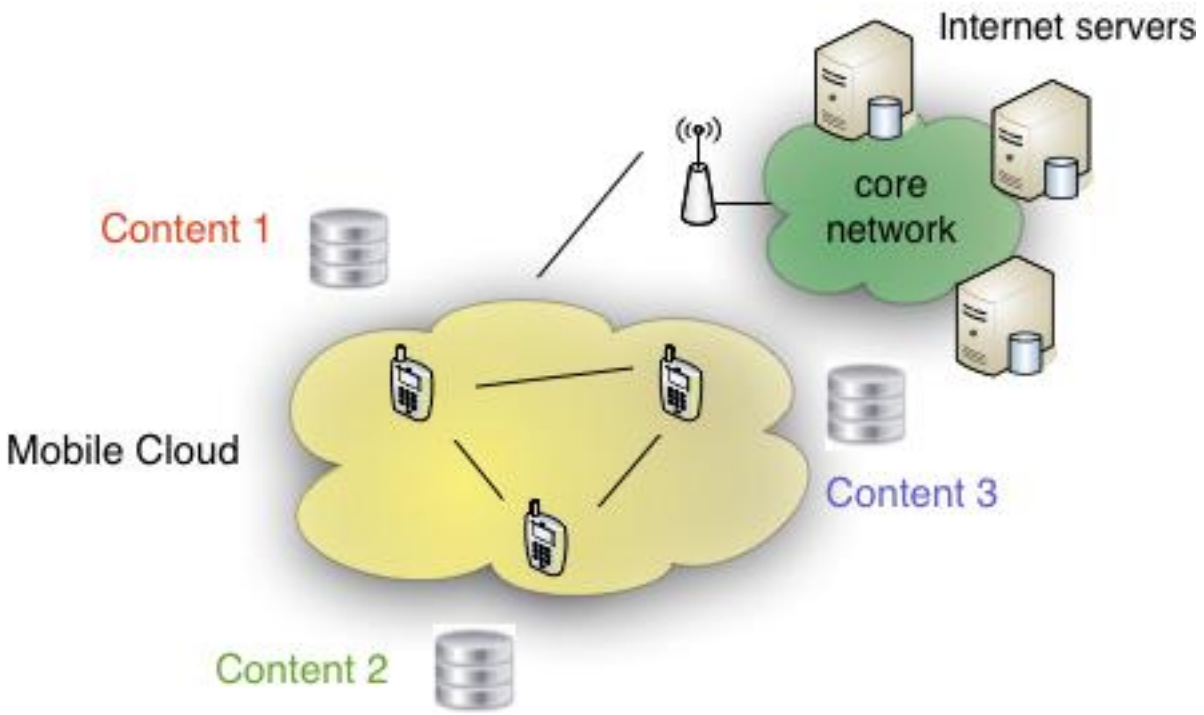
Mobile Clouds: Applications

- **Efficient distribution of multimedia contents**
  - Cooperative video services exploiting mobile clouds
  - Video transfer and distribution
  - Broadcast, multicast, unicast
  - Improvements in energy efficiency of wireless devices, QoS, etc.



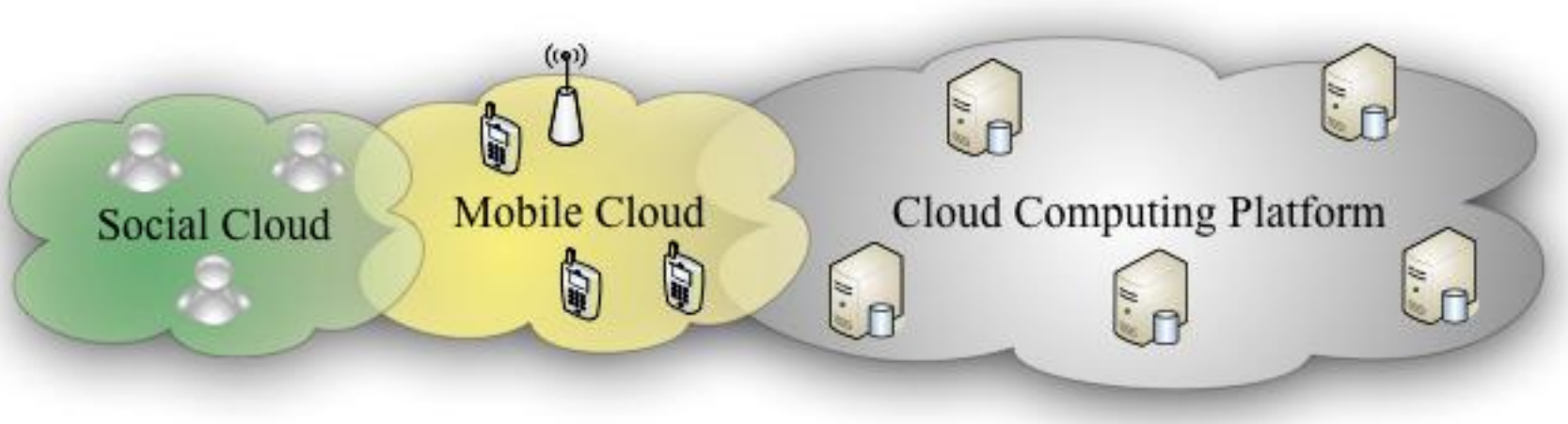
Mobile Clouds: Applications

- **Mobile Internet**
  - Accessing Internet through the cloud, idle devices help the one currently accessing Internet, parallel pipes of information.
  - Each user is interested in accessing a **different content**
  - Improvements in accessing time



Mobile Clouds: Applications

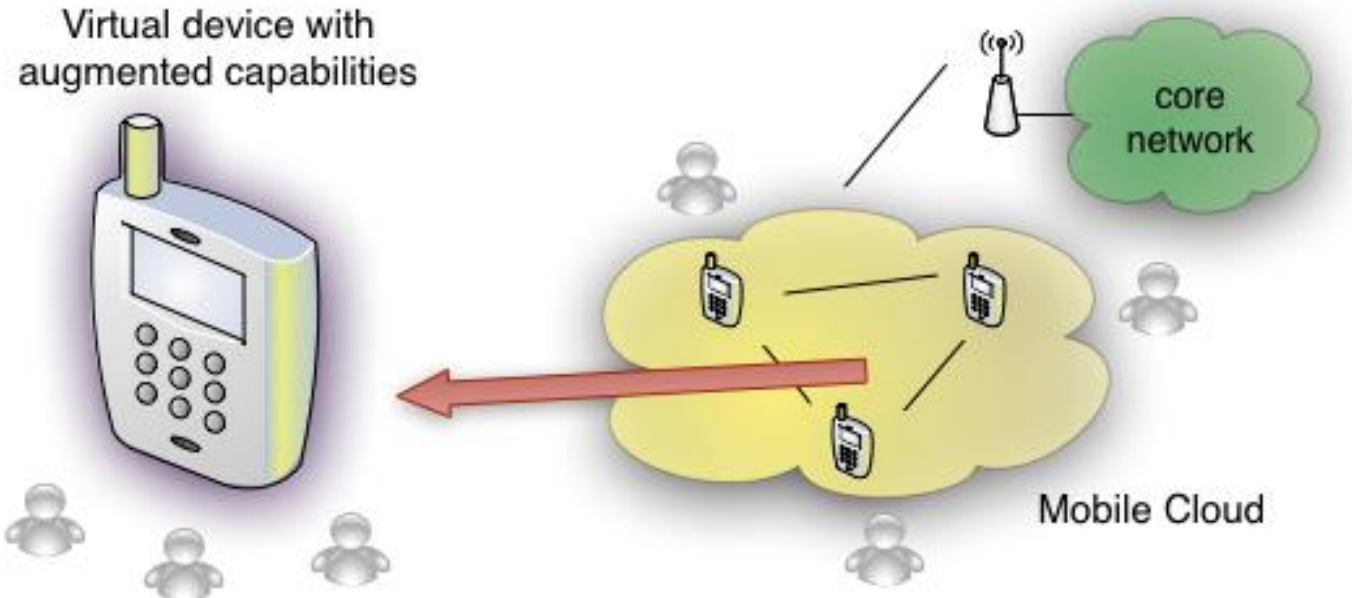
- **Cloud-2-Cloud**
  - A **mobile cloud** is an efficient and flexible way to connect users to a **cloud computing platform**
  - The MC can be seen as an interface between users and the cloud computing platform, improving robustness/reliability/QoS in the connection.
  - **x-as a service** concept, **x** = software, apps, infrastructure, processing power, resources, security, etc.



Mobile Clouds: Applications

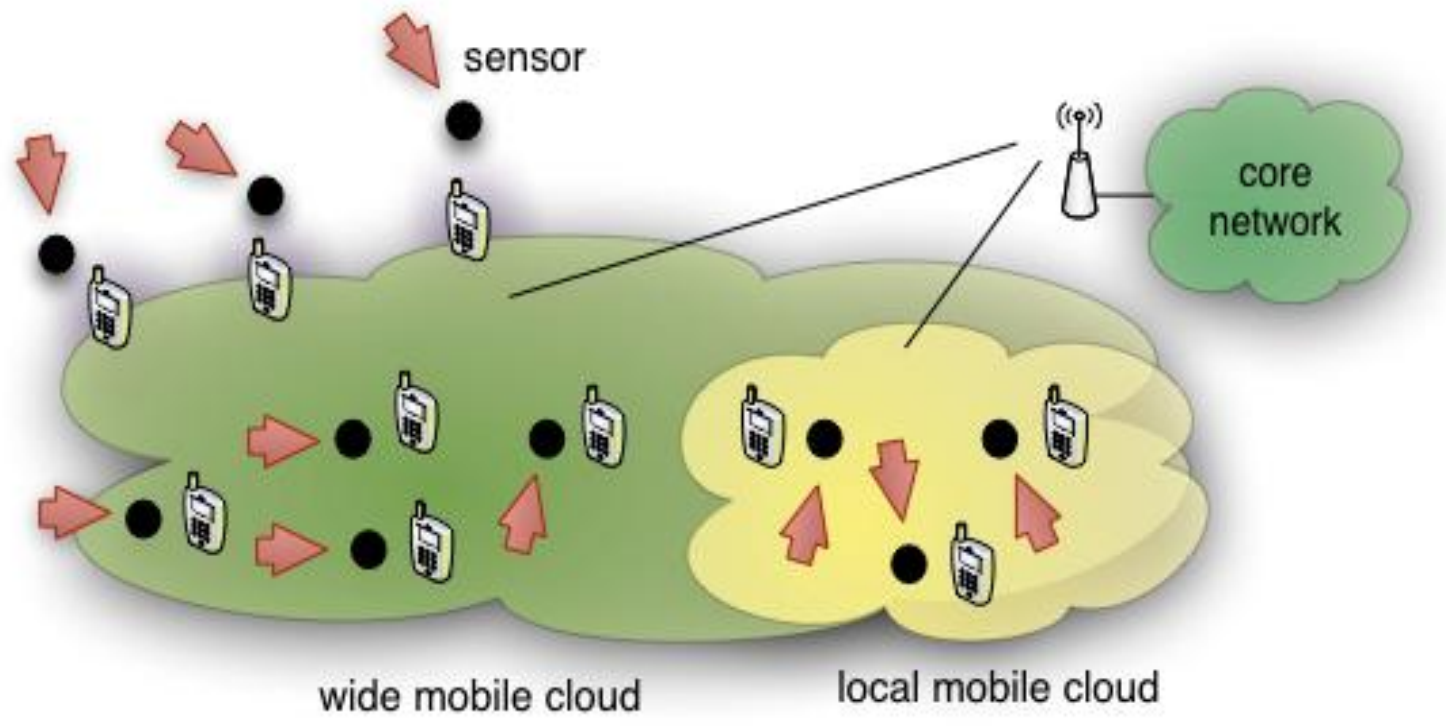
- **Virtual devices**
  - Many users can afford simple terminals, several uses can tie up together their wireless devices to form a “virtual device” or

    “virtual smart-phone” with augmented capabilities
  - Virtual device could support much higher data rates
  - Attractive approach for emerging economies



Mobile Clouds: Applications

- **Cloud Sensing/Massive sensing**
  - Creating 2D real-time maps of distribution of certain parameters such a temperature, pollution level, radiation level, pollen level, traffic, etc.

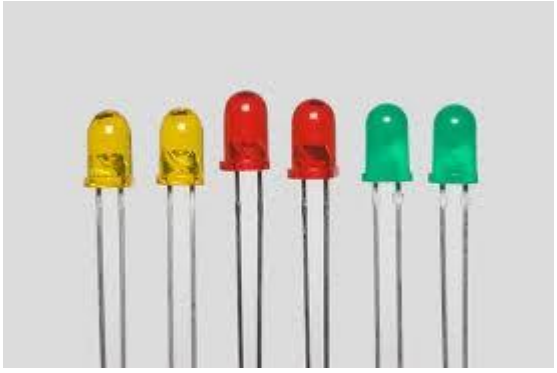


Mobile Clouds: Applications

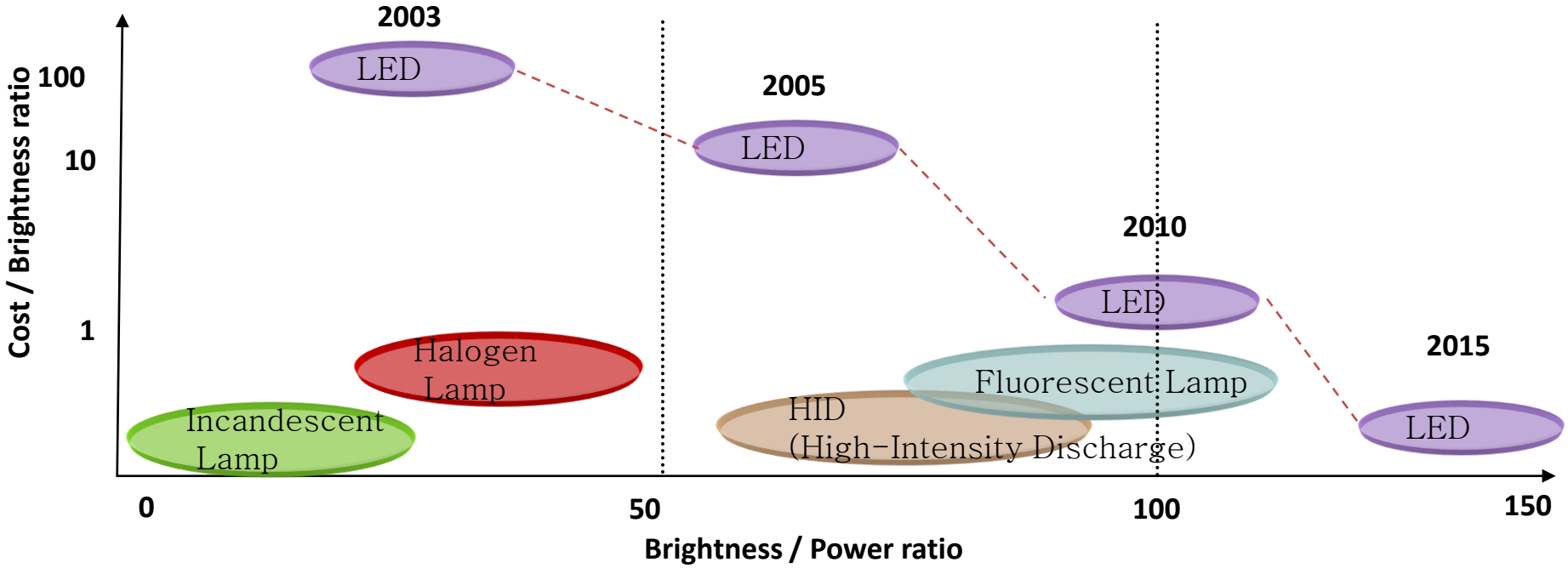
- **Other possible applications:**
  - Sharing sensors and actuators (microphones, CCDs, loudspeakers) to create special effects
    - 3D effects, directivity, etc.
    - Higher resolutions
  - Sharing processing power
    - CPU/DSP
    - Mass memory
  - Sharing Apps
  - Location information
  - Sharing contents

Visible Light Communications (VLC)

- LED technology well known and used since the 1970's (red, green, yellow)
- In the 1990's blue high efficient LEDs were developed, also easy to manufacture.
- This paved the way to the development of **WHITE LED**s
- Prof. Shuji **Nakamura** is credited with these developments.
- In 2006 Prof. Nakamura was awarded Finland's **Millennium Technology Prize** for his continuing efforts to make cheaper and more efficient light sources,



Visible Light Communications (VLC)



Source: Credit Suisse, 2006.11.2

Conventional vs. solid-state illumination

LEDs for Indoor Illumination

Visible Light Communications

- **Visible light communications** is a **wireless** communications techniques using the medium of **light** (e.g., **photons**) instead of **radio waves**.

- Light, which can be seen by the human eye, carries an embedded information signal, which is unseen.

- Work started in Japan in year 2000 approximately

- In January 2010 a team of researchers from Siemens and Fraunhofer Institute for Telecommunications (Heinrich Hertz Institute in Berlin) demonstrated transmission at 500 Mbit/s with a white LED over a distance of 5 metres (16 ft), and 100 Mbit/s over longer distance using five LEDs

Visible Light Communications

Advantages:

- **No use** of scarce and expensive **radio spectrum**
- Support of **very high data rates** (up top 10 Gbits/s)
- Unexpensive or free infrastructure
- No radio exposure
- Intuitive communications
- Low power
- Low cost

Secure communications (simple shielding by opaque surfaces, improved privacy)

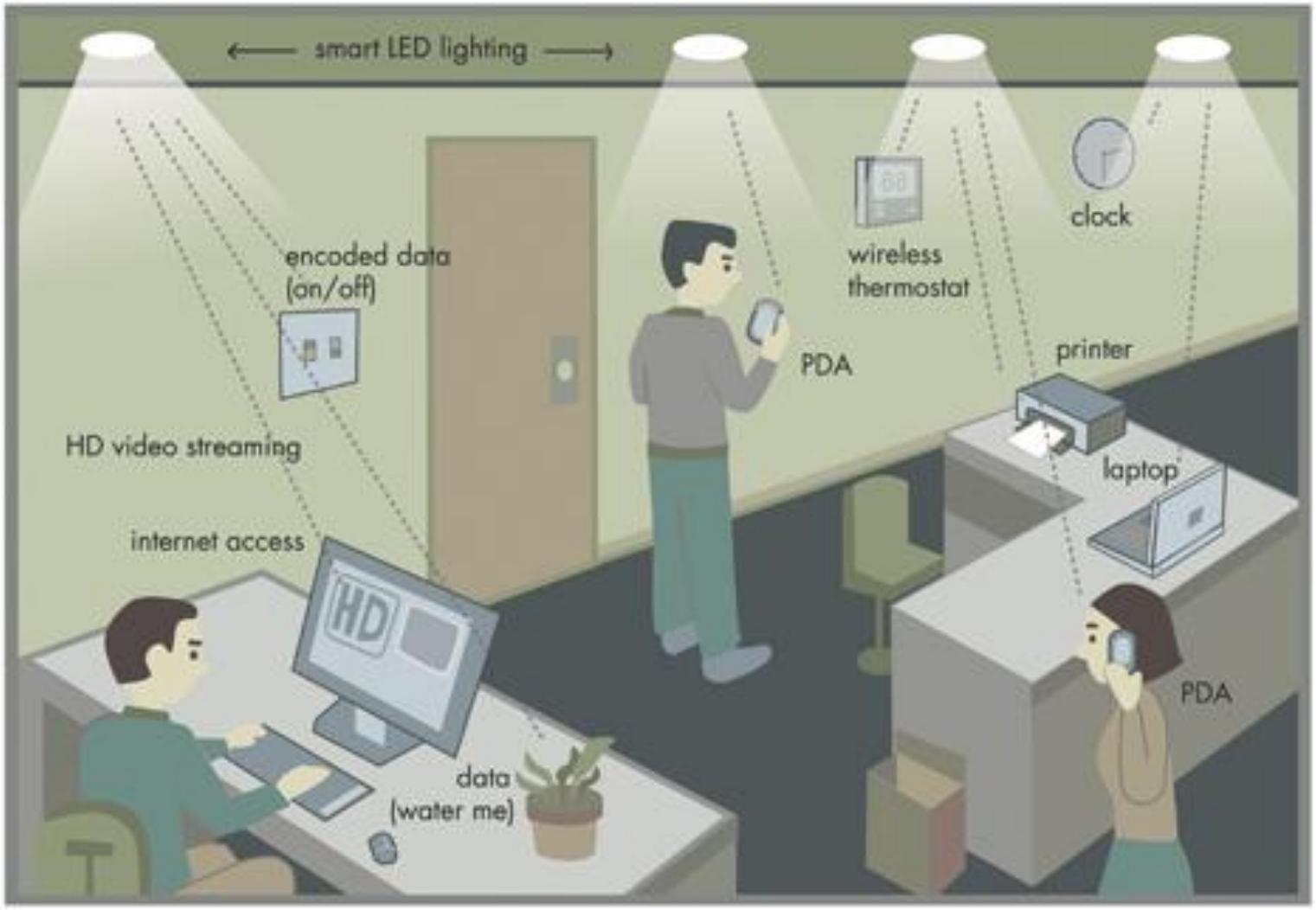
- No electromagnetic interference (EMI) with radio systems, no e-smog
- Optical and radio communications complement each other

Visible Light Communications

Applications:

- **WiFi Spectrum Relief** - Providing additional bandwidth in environments where licensed and/or unlicensed communication bands are congested
- **Smart Home Network** – Enabling smart domestic/industrial lighting; home wireless communication including media streaming and internet access
- **Commercial Aviation** – Enabling wireless data communications such as in-flight entertainment and personal communications
- **Hazardous Environments**- Enabling data communications in environments where RF is potentially dangerous, such as oil & gas, petrochemicals and mining
- **Hospital and Healthcare** – Enabling mobility and data communications in hospitals
- **Defence and Military Applications** – Enabling high data rate wireless communications within military vehicles and aircraft
- **Corporate and Organisational Security** – Enabling the use of wireless networks in applications where (WiFi) presents a security risk
- **Underwater Communications** – Enabling communications between divers and/or remote operated vehicles
- **Location-Based Services** – Enabling navigation and tracking inside buildings.

Visible Light Communications



Visible Light Communications

Applications:

Using VLC technology in an aircraft

Using VLC technology at the office

A VLC standard already was recently developed: IEEE802.15.7

Visible Light Communications

Challenges:

- Well suitable for downlink (DL), uplink (UL) is an open issue (some solutions exists, including IR UL, radio based UL)
- Competition with radio
- Ambient light
- Dependence on geomerty of the environment
- Light easily obstructed

Thank You!

marcos.katz@ee.oulu.fi