

Visible Light Communication (VLC)

Sustainable Energy-Efficient Wireless Applications Using Light

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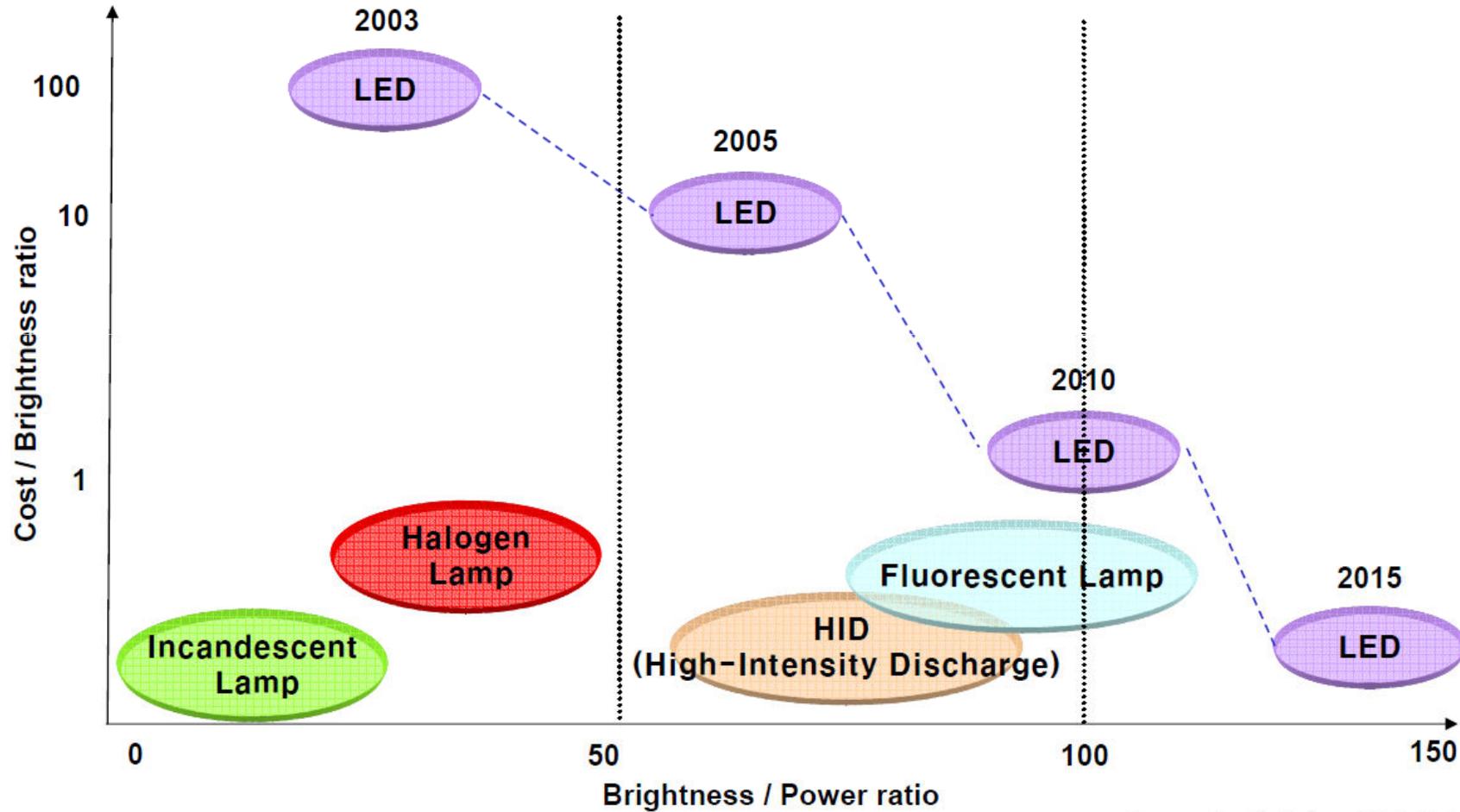
Outlines

- Introduction
- Motivation and Benefit
- Overview
- Demonstration
- Energy-Efficient Communication
- Conclusions

Introduction

- Lighting is a major source of electric energy consumption
 - It is estimated that 1/3 of global consumption of electricity is spent on lighting purposes
- Fluorescent lamps contain environmental pollutants
 - The replacement of Light emitting diodes (LEDs) generating white light will reduce energy consumption
- It is fortune that White LED (WLEDs) are already commercially available
 - Roughly 20 times and 5 times less power than conventional light source and fluorescent bulbs

LED Technical Evolution



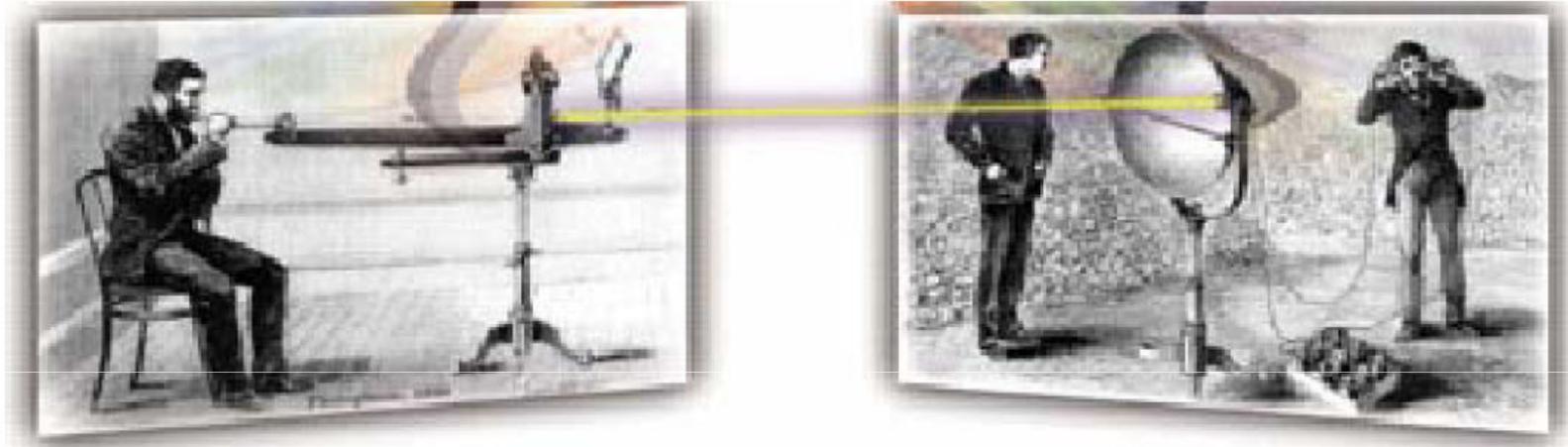
Source: Credit Suisse, 2006.11.2

Introduction

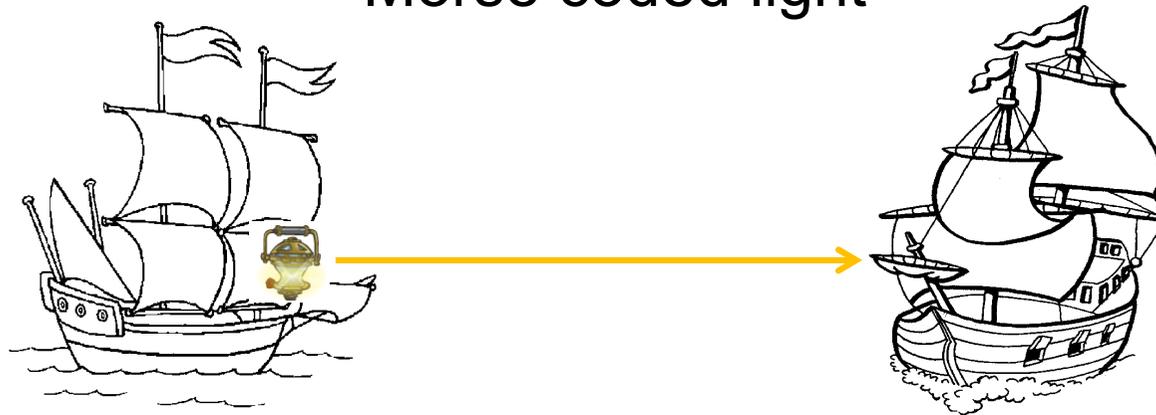
- Switching to Solid State Lighting (SSL) would
 - Reduce global electricity use by 50 %
 - Reduce power consumption by 760 GW in U.S. alone over a 20-year period
- If all existing bulbs were replaced by WLED
 - 1.9×10^{20} joules energy saving
 - 1.83 trillion USD financial saving
 - 10.68 gigatons reduction of carbon dioxide emissions
 - 962 million barrels less consumption of crude oil

The History of Visible Light Communicating

Photophone by Graham Bell in 1880



Morse coded light



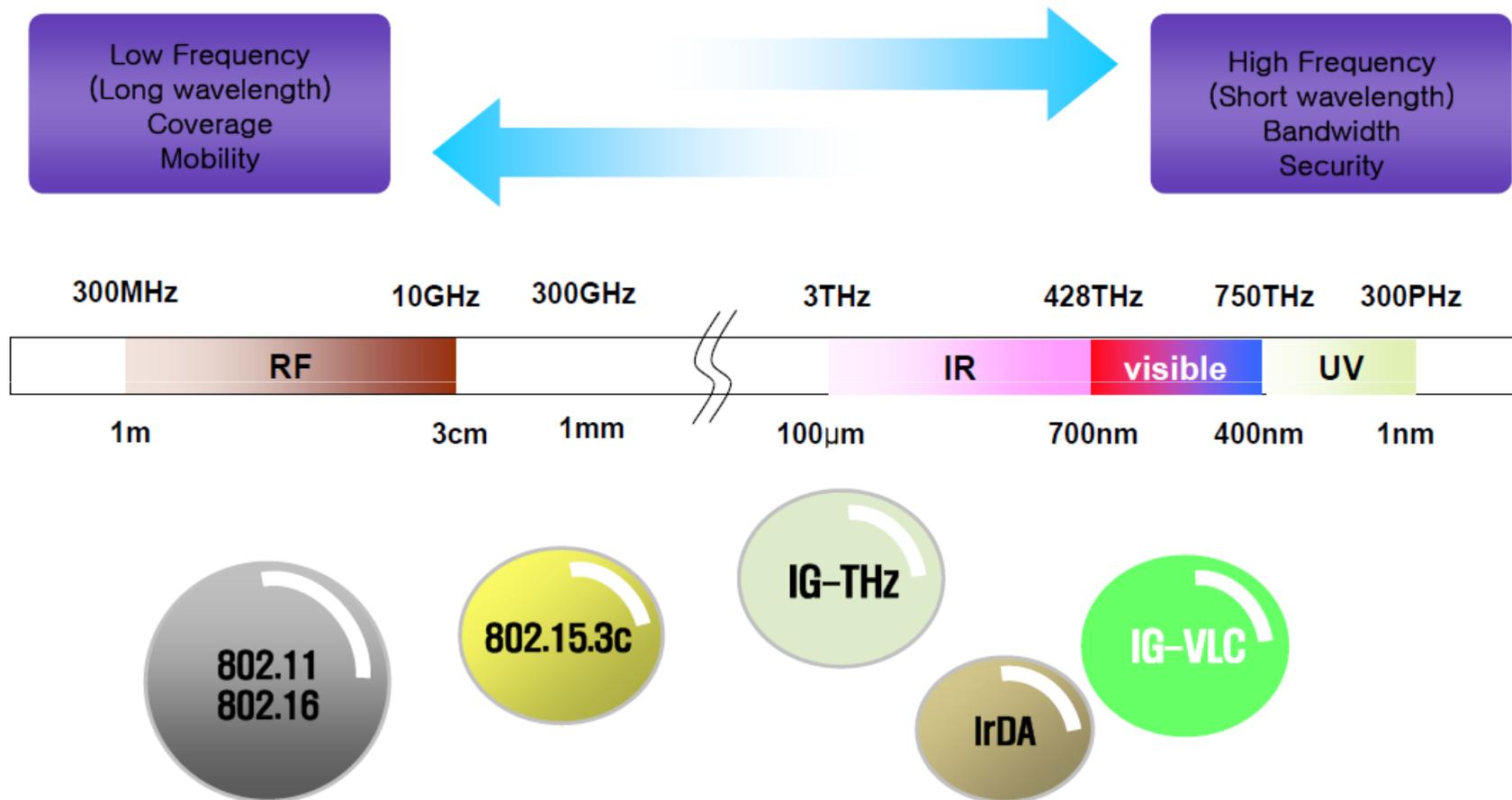
VLC Researches

- First research can be traced to as early as 1998-1999
- Contribution addressing broadband VLC using WLED started appearing in 2001
- Visible Light Communication Consortium (VLCC) was established in November 2003
 - Members includes Toshiba, NEC, KDDI, Sony, etc
- WWRF showed a few more contributions between 2000 and 2006
- IEEE issued a Call for contributions on IEEE 802.15.7 VLC in 2009 and held the first meeting

Motivation

- About 10 years ago, researchers came to the realization that WLED devices could also be used for wireless communication purposes
 - LEDs tends to be considerable cheaper than RF
 - Optical wireless allows easy bandwidth reuse and improve security
 - It does not generate RF contamination
 - Replacing RF device will reduce interference in RF band
 - RF radiation in hospital, airplane, and mine will be vanished
 - Large amount energy can be saved

Frequency Band for VLC



- IG-THz : 300 GHz to 10 THz (contribution 15-07-0623-01)
- 802.15.3c : 57 GHz to 64 GHz
- IrDA : 334THz(900nm) to 353THz (850nm)

Source: IEEE 802.15.7

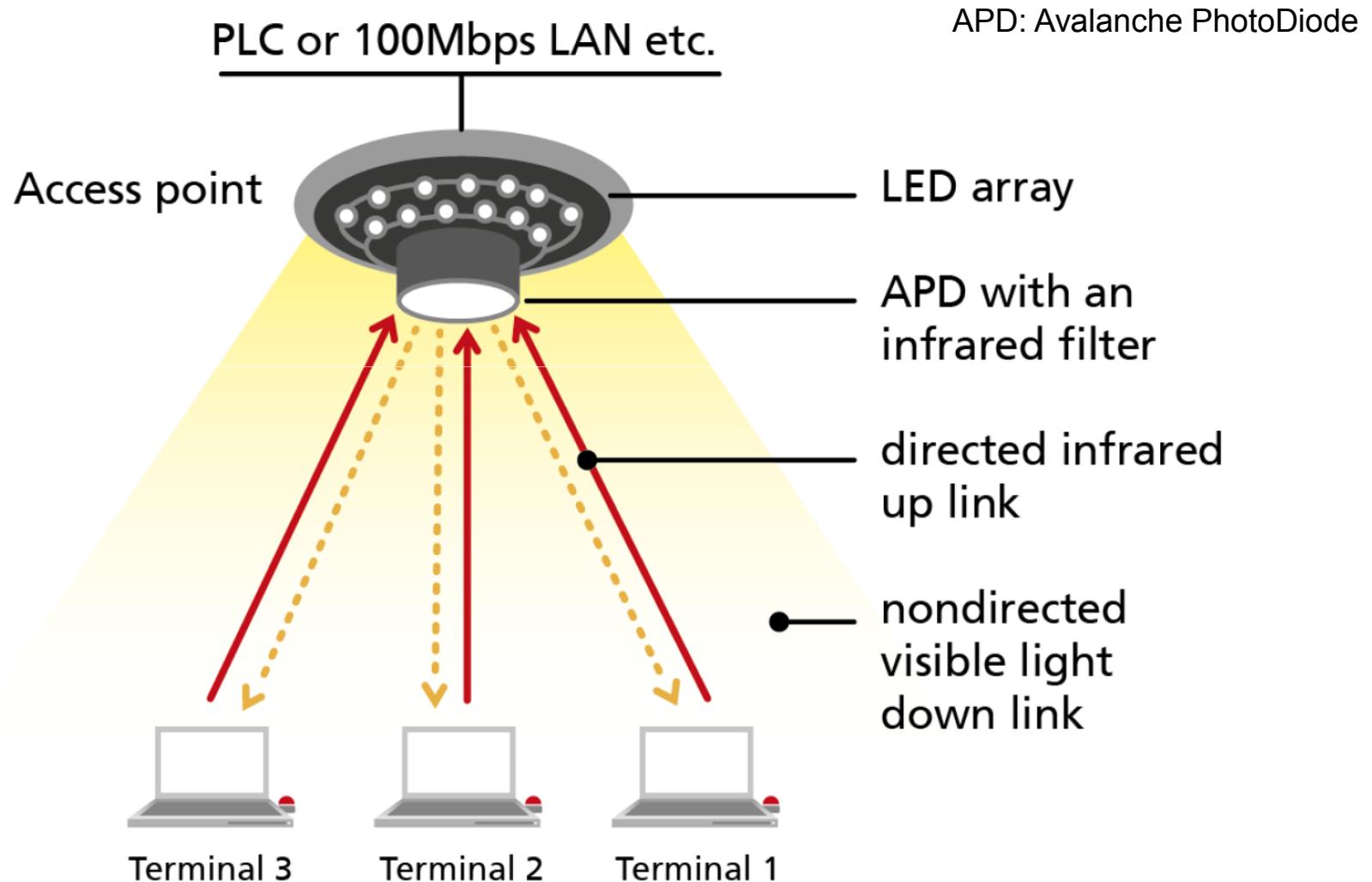
Why WLED?

- Indoor point-and-shoot links corresponding IR standard are installed in 100 million devices a year
 - Mainly digital camera and telephones
- The weakness of conventional wireless technologies
 - Expensive license band
 - Limited license-free band
 - Interference
 - Cost
 - Power consumption
 - Security
- In terms of indoor communications, only IR has been used
 - The reason is that until recently, it was not possible to manufacture highly efficient WLEDs
 - WLEDs can provide broadband, interference-free or at least interference-resistant technology, easy frequency reuse and affordable cost

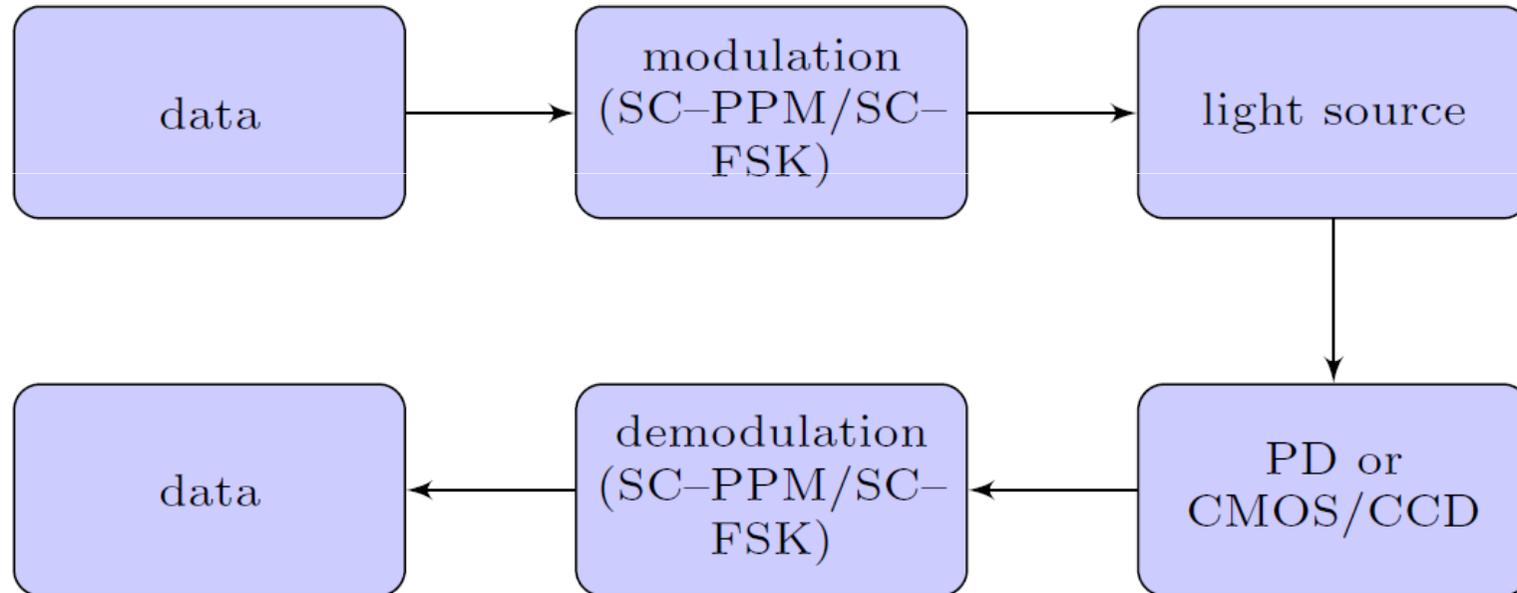
Benefits

- The advantages of using optical radiation over RF include:
 - Virtual unlimited bandwidth with over 540 THz for wavelengths in the range [200-1550nm]
 - Free and immediate utilization
 - Use of baseband digital technology
 - Compatible hardware design
 - Spatial diversity eliminates multi-path fading
 - Full utilized emission
 - Optical signals allows secure data exchanging
 - Physical-layer security
 - No electromagnetic interference with other devices
 - Immune to electromagnetic interference (EMI)

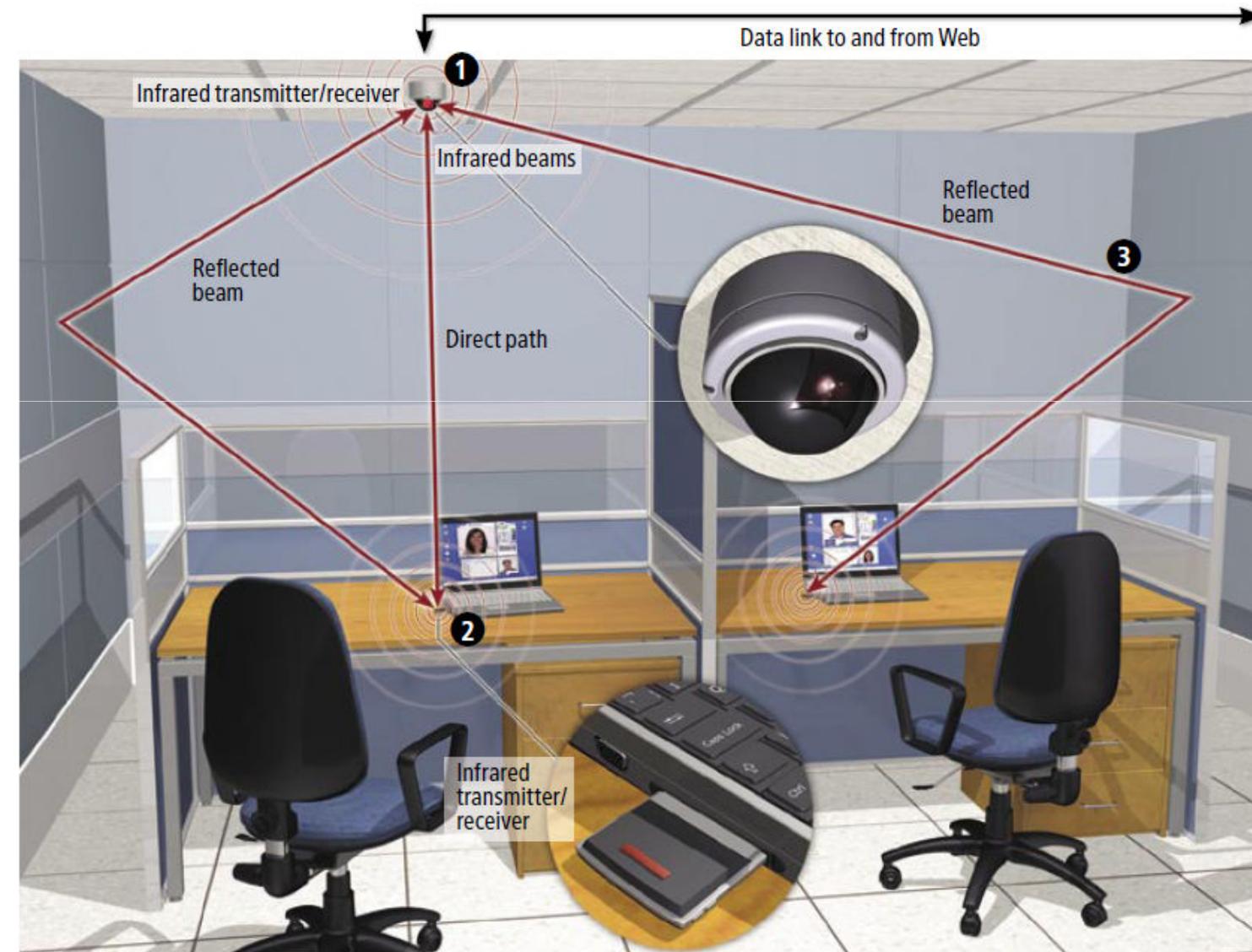
Schematic Diagram based on WLED modulation



Viable Light Communication Process

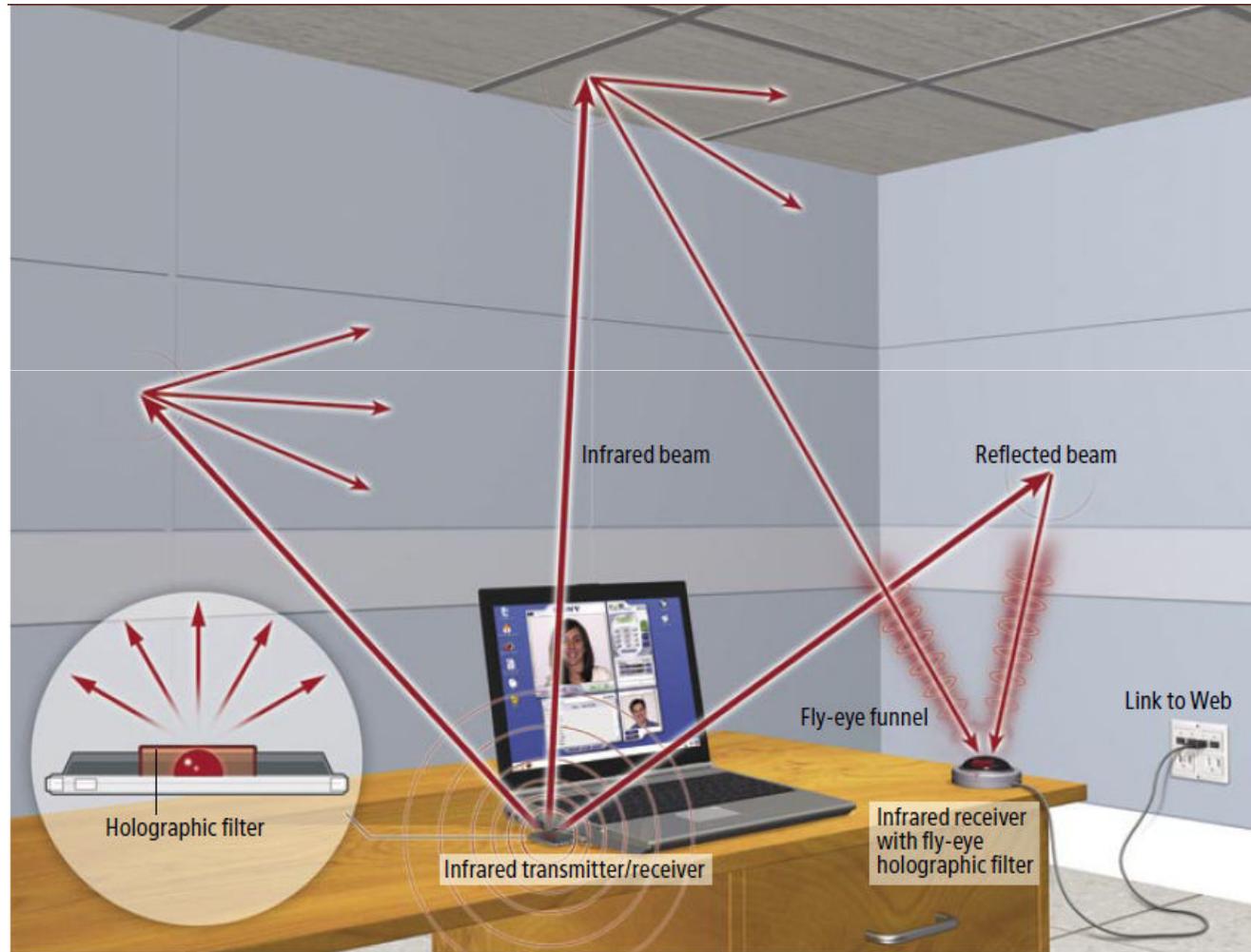


Indoor VLC Scenario



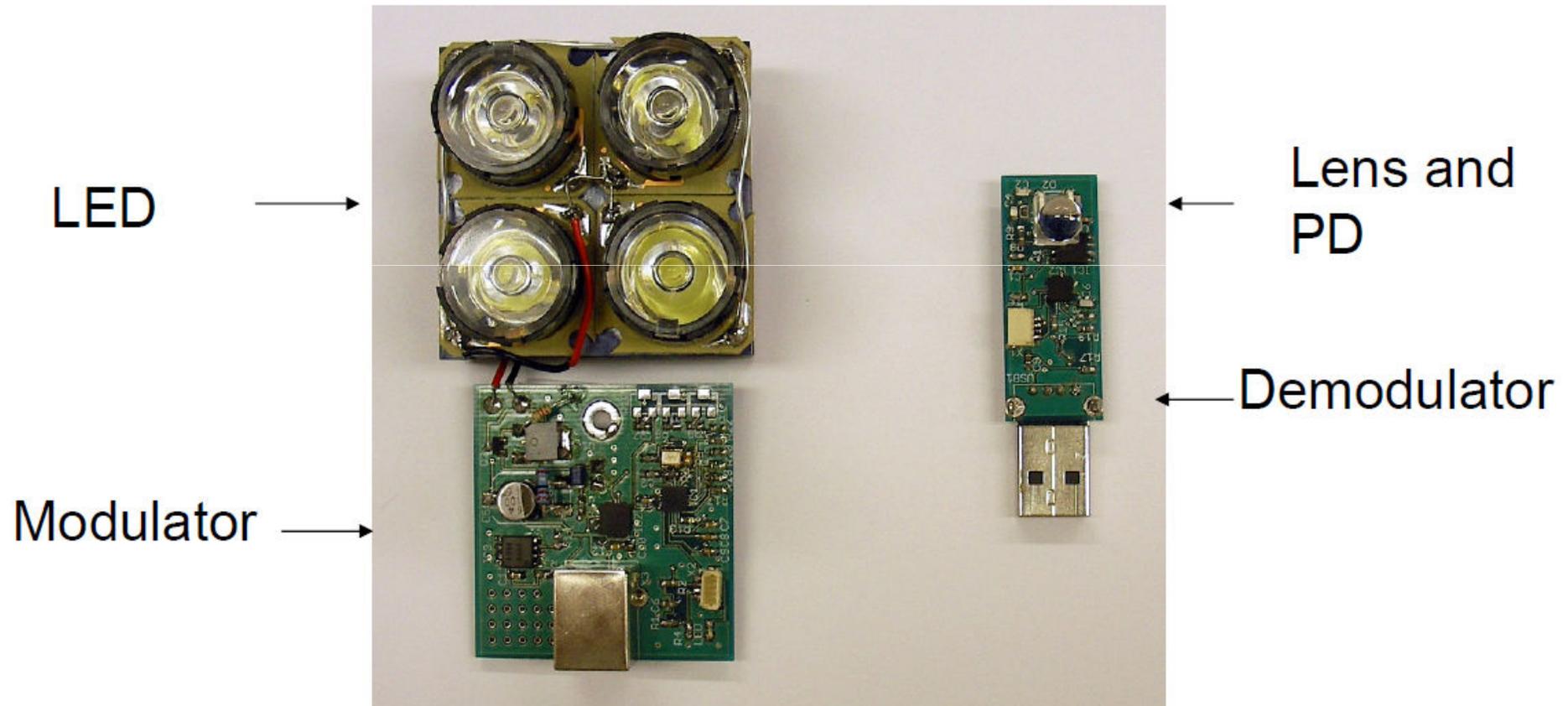
Source: Scientific American, July 2007

Holographic Filters Defeats Echoes



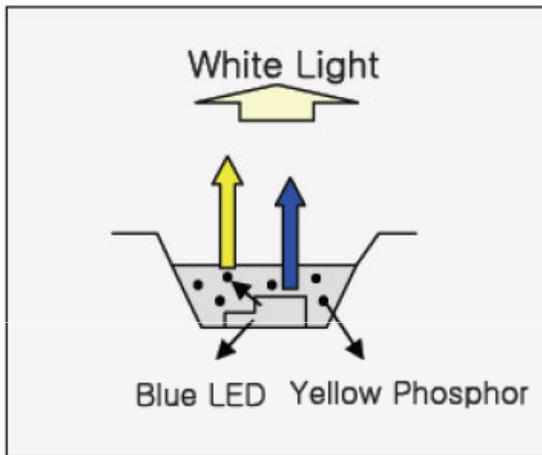
Source: Scientific American, July 2007

Visible Light ID kit



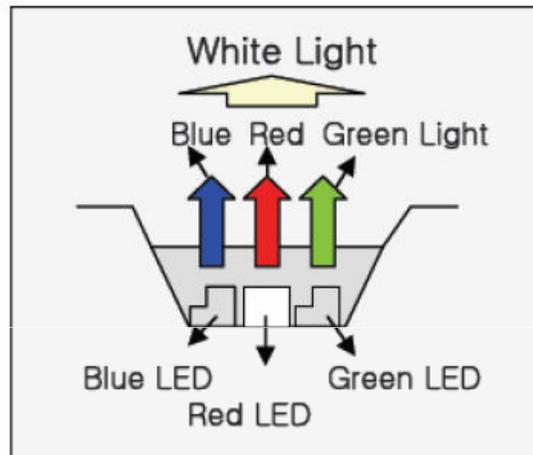
Source: M. Nakagawa, Keio University

LED Modulation Characteristic



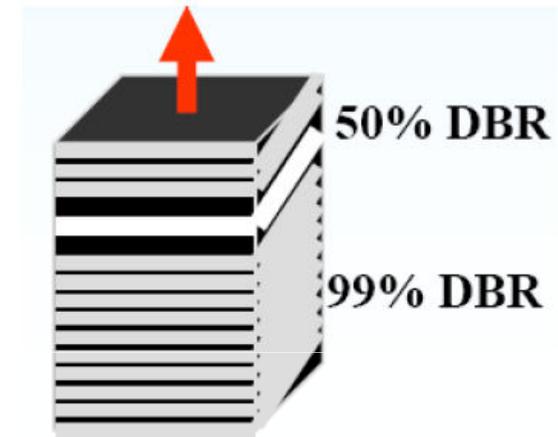
B + Phosphor LED

~40 Mbps



R+G+B LED

~100 Mbps



RCLED

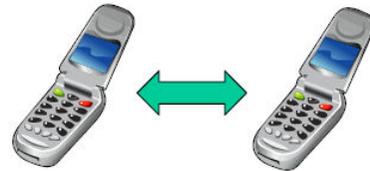
~500 Mbps

RC LED: Resonant Cavity LED

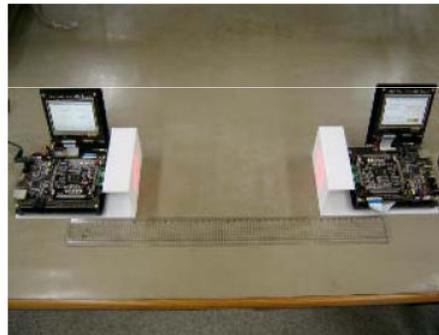
Source: IEEE 802.15.7

Demonstration – P2P

Mobile to mobile



Infra to mobile



100 Mbps, 1m
Bidirection



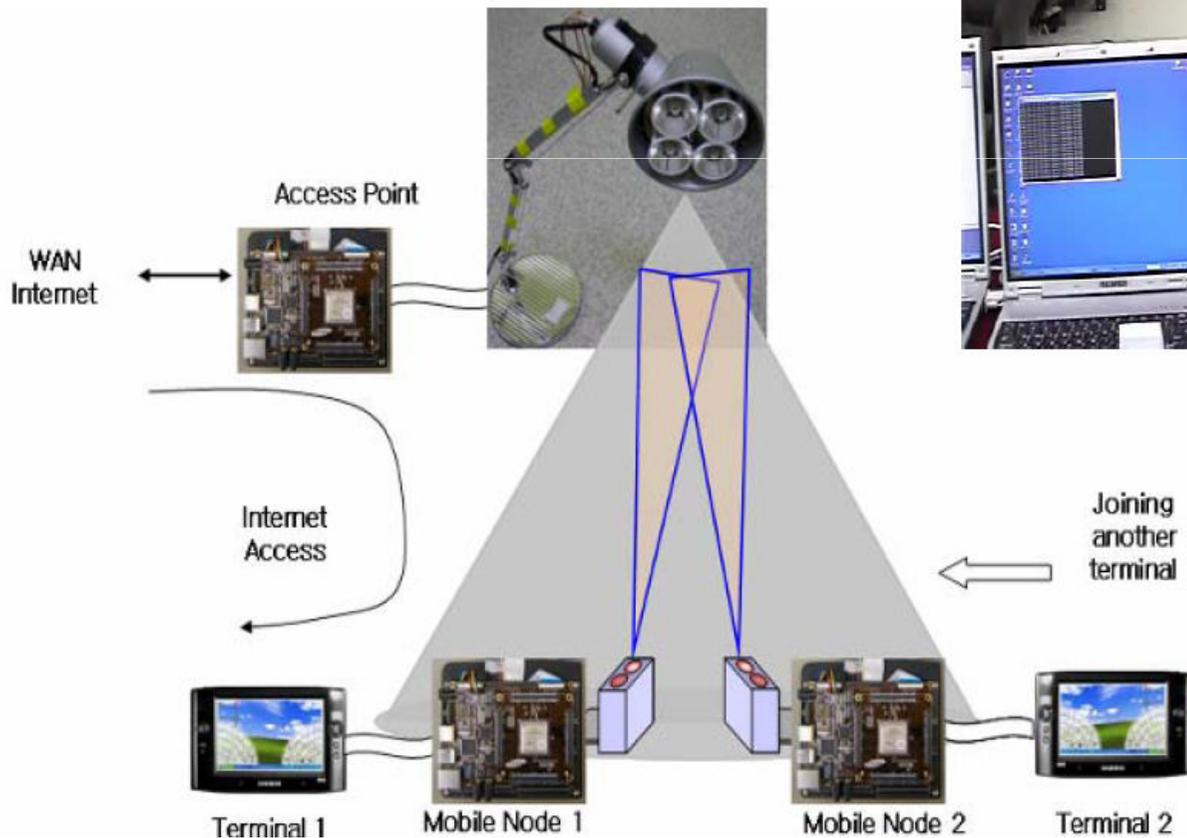
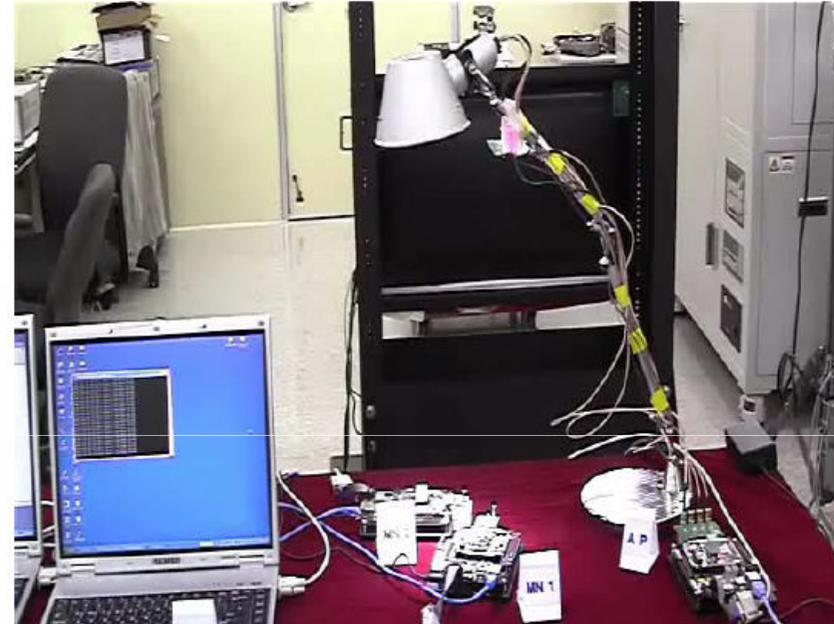
20 Mbps, 3m
Unidirection

Source: IEEE 802.15.7

- Seimens scientists reported a VLC system using WLED to transmit a data at 500 Mb/s over 5m
- Author's group reported an IR laser link transmitting data at a rate 1Gb/s over a 7m directed/non-LOS optical path

Demonstration – P2MP

- TDMA-based P2MP
- 4 Mbps, 3 m, bi-direction
- Secure indoor LAN

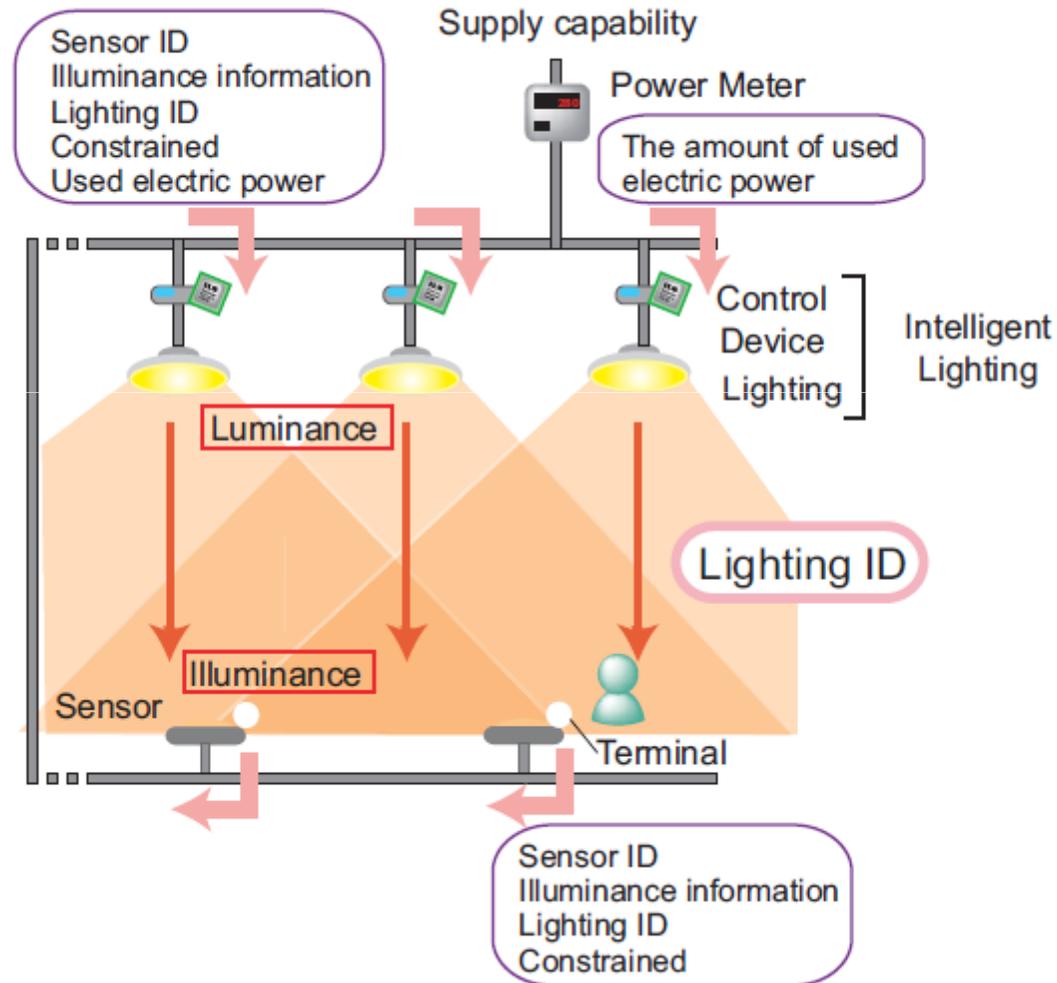


Source: IEEE 802.15.7

Energy-Efficient Communication

- WLEDs are considered strong candidates for the future of lighting technology
 - High brightness, very low power consumption, and high lifetime expectancy
- It is predicted that WLEDs will reach 7W and 1000 lumens and replace traditional lamps in 2012
- VLC technology has potential in a number of specialized application areas, including
 - Hospital and healthcare
 - Hazardous environment
 - Commercial aviation
 - Corporate and organizational security
 - Wi-Fi spectrum relief
 - Green Computing
 - Defense and military applications
 - Underwater communications

Intelligent Lighting System Using VLC



Conclusions

- This paper discuss the applications of optical wireless communications system using visible light
- WLED can be used not only for lighting the homes but also as means for wireless in-house communication
- VLC can create a revolution in the area of consumer networking because of efficiency and affordability