LEDucation

Designers Lighting Forum

Introduction to LiFi

Randy Reid

12 MAR 2019

AIA Objectives

- Identify the appropriate applications for LiFi
- Analyze the potential for LiFi to change the lighting industry
- Describe how LiFi works
- Understand the two types the of LiFi and which devices are best suited for each type
- Know the limitations of LiFi and how it will enhance WiFi
- Explain where LiFi fits with 5G

Wherever there is illumination, there is Internet.

History

- Professor Harald Haas coined the term "Li-Fi" at his 2011 TED Global Talk where he introduced the idea of "wireless data from every light"

- The general term visible light communication (VLC) whose history dates back to the 1880s, includes any use of the visible light portion of the electromagnetic spectrum to transmit information

New Terms

- VLC: Visible Light Communication
- OCC: Optical Camera Communication
- OWC: Optical Wireless Communication
- V2V: Vehicle to Vehicle transmissions
- LoS: Line of Sight
- Latency: time it takes to get a response from the access-point

Definition

LiFi is a wireless optical networking technology that uses light-emitting diodes (LEDs) for data transmission

- By switching a LED on and off several thousand times a second, data can be transmitted in computing language, in 01110... format. The frequencies are not visible to the naked human eye, too fast to have any physiological impact. (up to 1 Mhz)

A high tech Morse Code
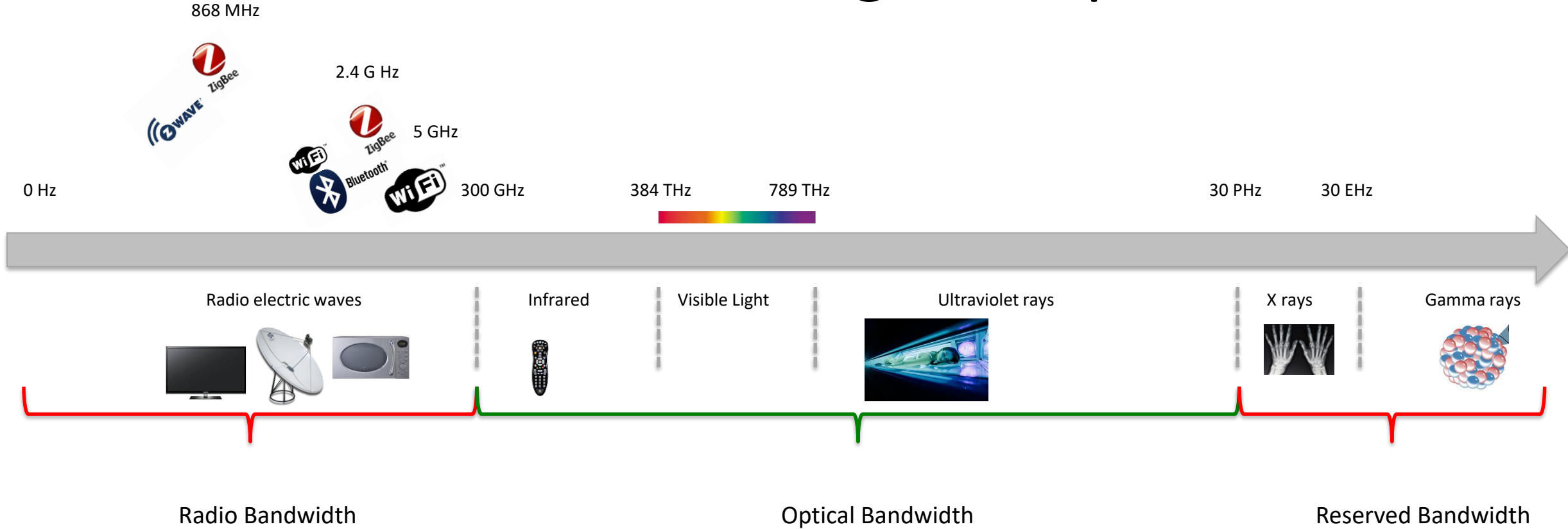
Benefits

- Speed
  - 2018: 30-50 mbps
  - 2019:   100 mbps (infrared)
  - Theoretical: 224 kbps
- Security
  - *Essentially* Line of Sight
- No EMI
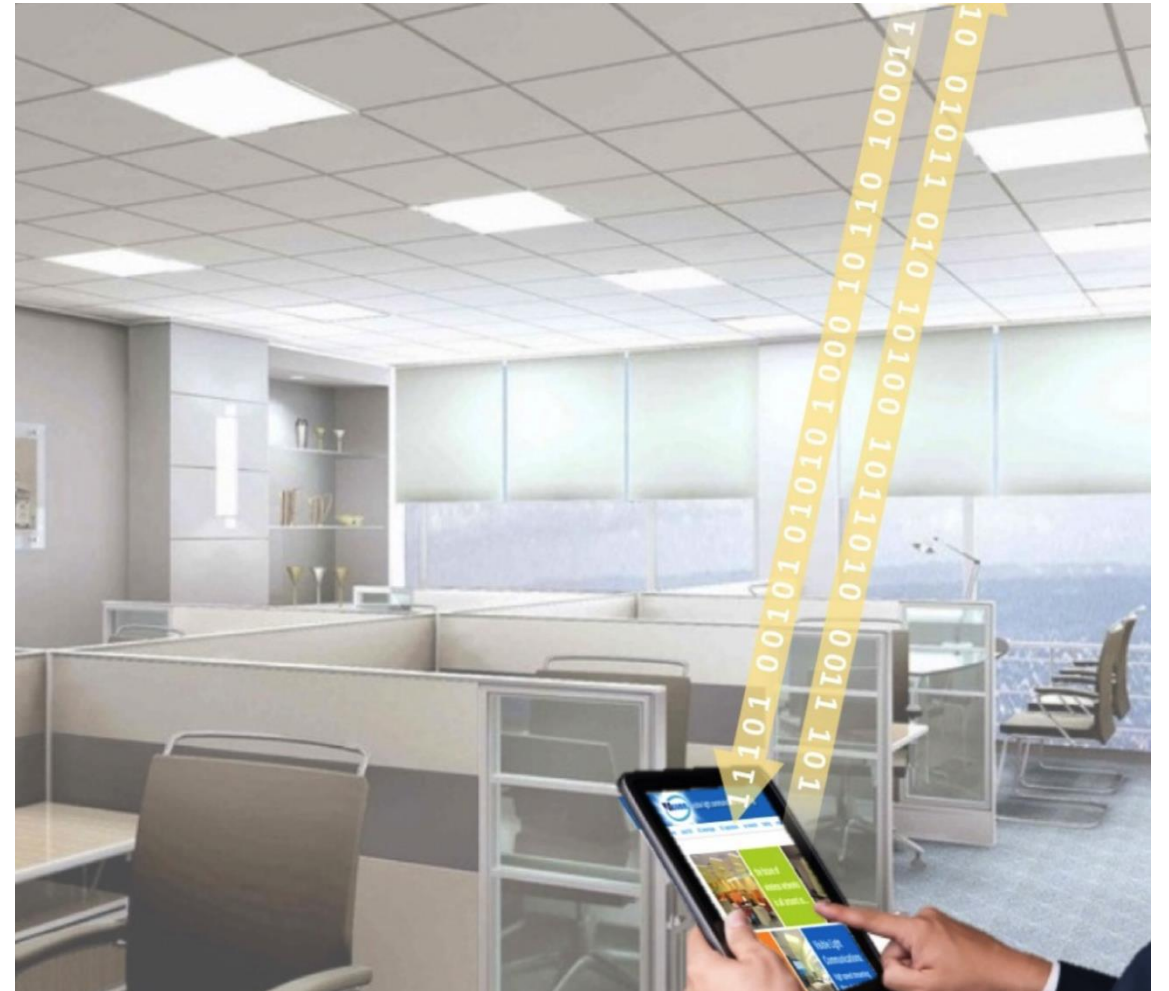
How it works...

- The information (music, movies, texts...) coming from the Internet reaches a LiFi modem. The LiFi modem will change all these information into a succession of 0 and 1 called binary coding.

- Each time the LED lighting will receive a 0 or a 1 code, it will switch off and on respectively.

- Human eyes could not see this switching but a special LiFi key will decode the optical signal contained into the light and send them to a computer.

- The computer will change the binary coding in a clear and comprehensible way for humans. Hence, the lighting network of buildings could be used to connect people to Internet.

Use of the ElectroMagnetic Spectrum*

868 MHz

2.4 G Hz

5 GHz

| 0 Hz | 300 GHz | 384 THz | 789 THz | 30 PHz | 30 EHz |

Radio electric waves | Infrared | Visible Light | Ultraviolet rays | X rays | Gamma rays

Radio Bandwidth

Optical Bandwidth

Reserved Bandwidth

The size of the infrared and visible light spectrum together is approximately 2600 times the size of the entire radio frequency spectrum of 300 GHz

*Not to scale

9

leducation.org

The Future of the Connected World*

- Number of connected devices is expected to reach 50 billion by 2020

- 41% of the data was delivered over Wi-Fi in 2016, this number is projected to reach 73% in 2021

- Traffic over Wi-Fi will increase 640% by 2021

*Mohammad Noshad, VLNcomm

Issues with Wi-Fi

Throughput limitations

- The data-rate in Wi-Fi systems (2.4, 5 and 60 GHz bands) is a very narrow part of the spectrum support to a limited number of users and devices in crowded areas
- Limited capacity - speed is divided among users
    Limited bandwidth reuse

The resolution of virtual reality image and immersive video and autonomous drivers needs to approximate to the amount of detail the human retina can perceive. It is important to have a low latency (< 1 msec) in real-time applications

- The latency of a 4G network cannot meet this requirement
- With the latency of 4G network, a car driving at 100 km/h still moves 1.4 m until the braking command is executed

leducation.org

Problem: Wi-Fi has Limitations

Security & Privacy

RF is hard to contain and can be externally intercepted.

Emergent Applications

Wi-Fi and BLE has low resolution for real-time location services (RTLS).

Signals are carried
on radio-frequency
(RF)

Interference & Safety

RF Interferes with safety-critical systems.
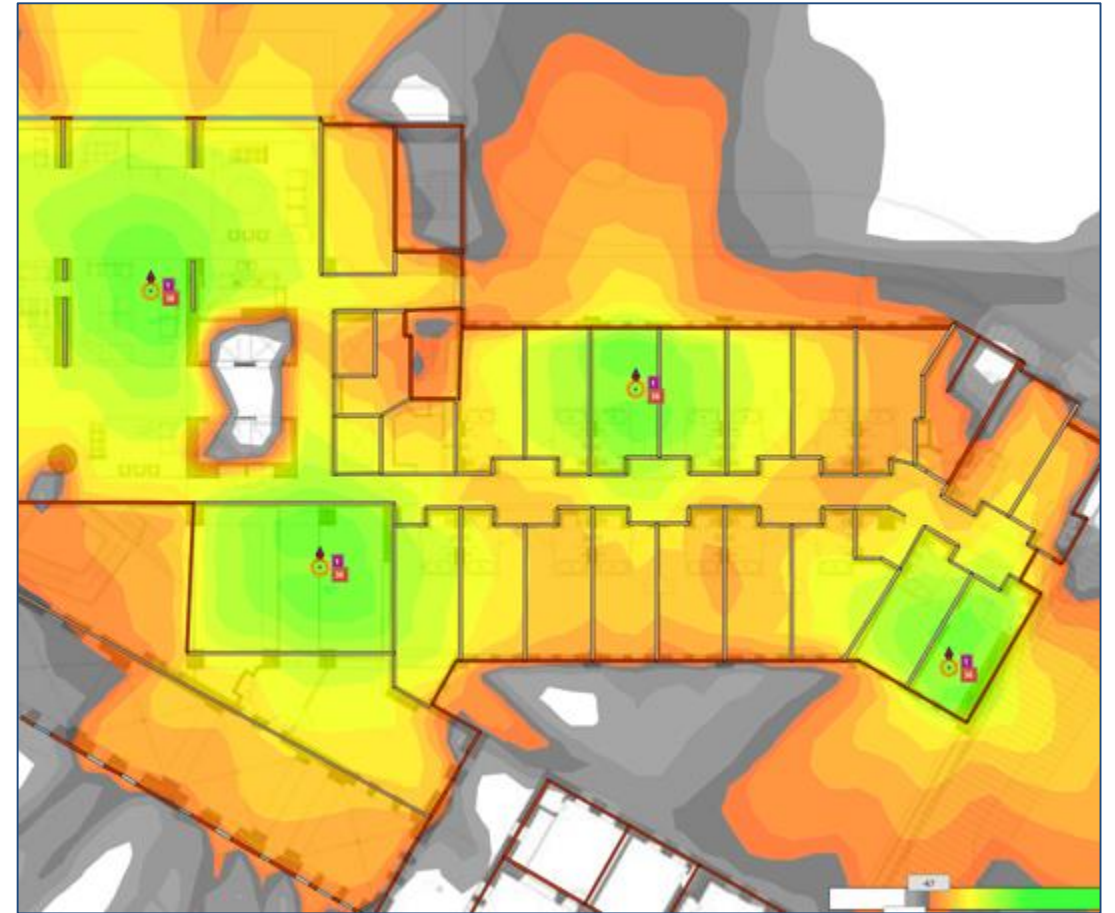
Capacity & Latency

So many connected devices cause network congestion.
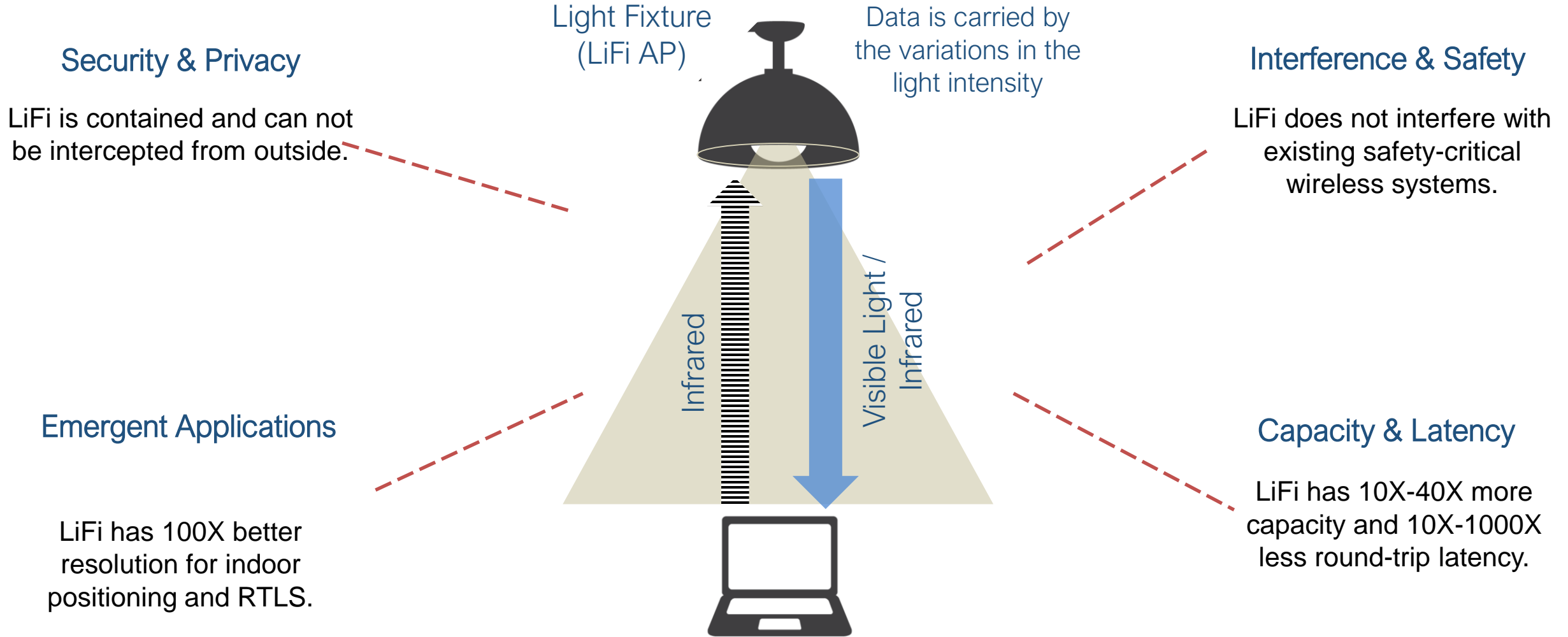
leducation.org

Wi-Fi Pervasiveness is a Blessing and a Curse

- We want Wi-Fi to be in every room, every space

- Signals carried on RF naturally penetrate walls, doors

- As a result, Wi-Fi is susceptible to eavesdropping and hacking

- Thus, Wi-Fi is banned in many settings e.g. DoD, banks, etc.

13

Solution: Light-based networking (LiFi)

Light Fixture
(LiFi AP)

Data is carried by the variations in the light intensity

Security & Privacy

LiFi is contained and can not be intercepted from outside.

Interference & Safety

LiFi does not interfere with existing safety-critical wireless systems.

Infrared

Visible Light / Infrared

Emergent Applications

LiFi has 100X better resolution for indoor positioning and RTLS.

Capacity & Latency

LiFi has 10X-40X more capacity and 10X-1000X less round-trip latency.

Solution: 2 Types of LiFi

- Bi-Directional (PC's, laptops and pads)
  - Send and receive data through Light
  - Sometimes called Omni-Directional

- Mono-Directional (tablets and phones)
  - Receive data through Light
  - Sometimes called:
    - One-way LiFi
    - Visual Light Communications (VLC)

Bi-Directional LiFi
# Omni-Directional LiFi

Bi-Directional:

- P.O.E. Downlight is connected to router using <u>Cat 6a</u> cable
- LiFi device inserted between driver and LED array
  - Modulates the LEDs which allow for data to be sent

Dilemma

- Laptops, pads, and phones not equipped to send and receive LiFi signals

  - No USB port on phones or iPad

  - Awkward carrying a laptop with dongle dangling

- Optical cameras on pads and phones can receive data—but not transmit data
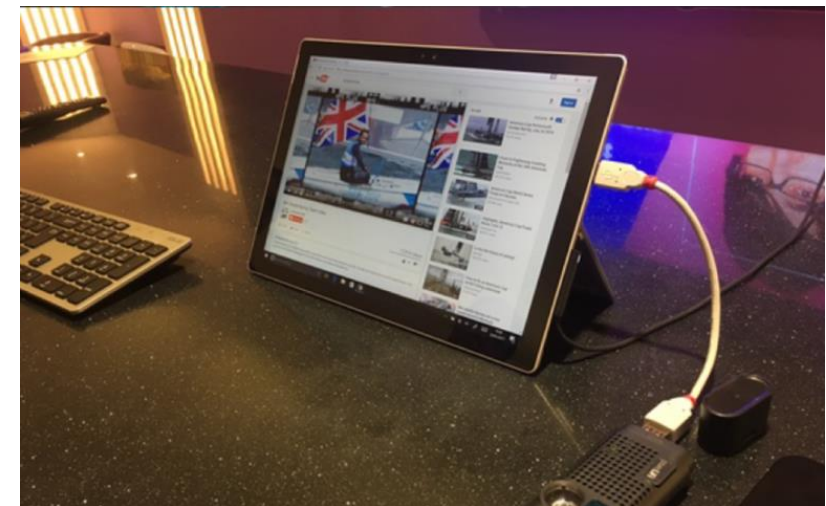
The Damn Dongle!

The Good News from Apple

- iOS has LiFi drivers built-in

iOS code shows Apple experimenting with ultra fast, light-based Li-Fi wireless data for future iPhones

By Sam Oliver
Monday, January 18, 2016, 08:55 am PT (11:55 am ET)

Recent versions of iOS have been found to contain references to Li-Fi, an experimental high-speed wireless networking protocol that uses pulses of light to transmit data and is being marketed as a long-term replacement for Wi-Fi.

Beginning with iOS 9.1, the operating system's library cache file makes mention of "LiFiCapability" alongside other hardware and software capability declarations. The change was spotted by Twitter user Chase Fromm and independently confirmed by AppleInsider.

Li-Fi works in a way not entirely unlike a traditional infrared remote control. Data is transmitted by rapidly modulating a light source, and received with a light sensor before being reassembled into an electronic signal.

Unlike your television remote, Li-Fi uses visible light and the modulation happens in a manner imperceptible to the human eye: that means the same bulb that lights your hallway can act as a data access point. It's also much faster, with theoretical throughput capacity of up to 224 gigabits per second.

Harold Haas TED Talk: Wireless data from every light bulb
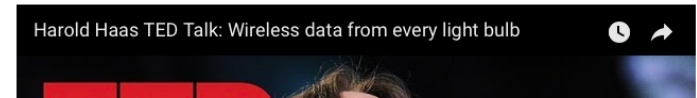
The Bad News from Apple

By Sam Oliver
Monday, January 18, 2016, 08:55 am PT (11:55 am ET)

leducation.org

Beta Sites
Bi-Directional

- 30 pilot projects
- US Army
- US Navy
- Airbus (3 planes in 2019)
- Auto CES

INCUBEX™
Building tomorrow's markets

ATEA

PILOTS
Li-Fi-enabled lighting will facilitate secure, wireless connectivity at all times and locations without any electromagnetic interference with sensitive radio equipment.

CABIN CREW
The aircraft cabin general illumination system will provide connectivity to cabin crew members anywhere in the cabin.

PASSENGER
Cabin reading lights will transport data to passengers' laptops, smartphones and tablets.

LEDucation

orange™

leducation.org

Underwater Li-Fi to be used by the Navy

- The specific uses for Li-Fi are infinite. For example, the [Navy](#) wants to employ the use of Li-Fi to enhance submarine communication systems. They currently use a slow and antiquated system for underwater communication that does not quite jibe well with the poor acoustics that lie underwater. [Radio waves](#) also do not travel efficiently underwater.

https://www.electronicproducts.com/Computer_Systems/Modules/Underwater_Wi-Fi_to_be_used_by_the_Navy.aspx

LiFi for Tactical Missions

https://www.army.mil/article/213936/seeing_the_light_lifi_will_revolutionize_it_on_mission_command_posts

Mono-Directional LiFi

Mono-Directional LiFi

- Requires use of mobile phone camera to always be on
  - Camera is capturing data, not images— little battery drain
  - Compatible with iPhone 5 thru iPhone 10, Samsung 6-9
- Can only receive signal through LiFi—cannot send

App Store 2:08 PM 46%

ZOne VLC

Activate Li-Fi by pressing toggle button

Li-Fi

Step into the foot steps to use Li-Fi

Li Fi

2 types of Mono-Directional

- Store-on-Phone
  - Takes up a lot of space in the phone

- Store-on-Cloud
  - Must be connected to WiFi or Cellular to obtain

Approximate speed 1 mpbs

- User scans QR code
  - Opt in agreement
  - Actually loading all data into phone
- LiFi device inserted between driver and LED array
  - Modulates the LEDs which allow for data to be sent
- Each luminaire has unique address
- Optical Camera Communications (OCC) in phone or pad captures address
  - Retrieves data packet synced to that address

- User scans QR code
  - Opt in agreement
- LiFi device inserted between driver and LED array
  - Modulates the LEDs which allow for data to be sent
- Each luminaire has unique address
- Optical Camera Communications (OCC) in phone or pad captures address, retrieves data
  - Data received via WiFi or Cellular

Success Stories
Bi-Directional

- French Grocery Retailer

- Carrefour

- Edeka

- Atlanta Airport

Recent Developments

5G

- 5G 'Last Mile' not settled
- 5G will offer download speeds of 100 mpbs*
  - How will 5G get to our home devices?
    - WiFi or LiFi

*25 FEB 2018, _The Verge_, "Qualcomm's Simulated 5G Tests Shows How Fast Real-world Speeds Could Actually Be."

LEDucation

education.org

Standardization

The IEEE 802.15 has two standards effort for OWC and the IEEE 802.11 has a topic interest group looking at the feasibility of introducing LC to 802.11
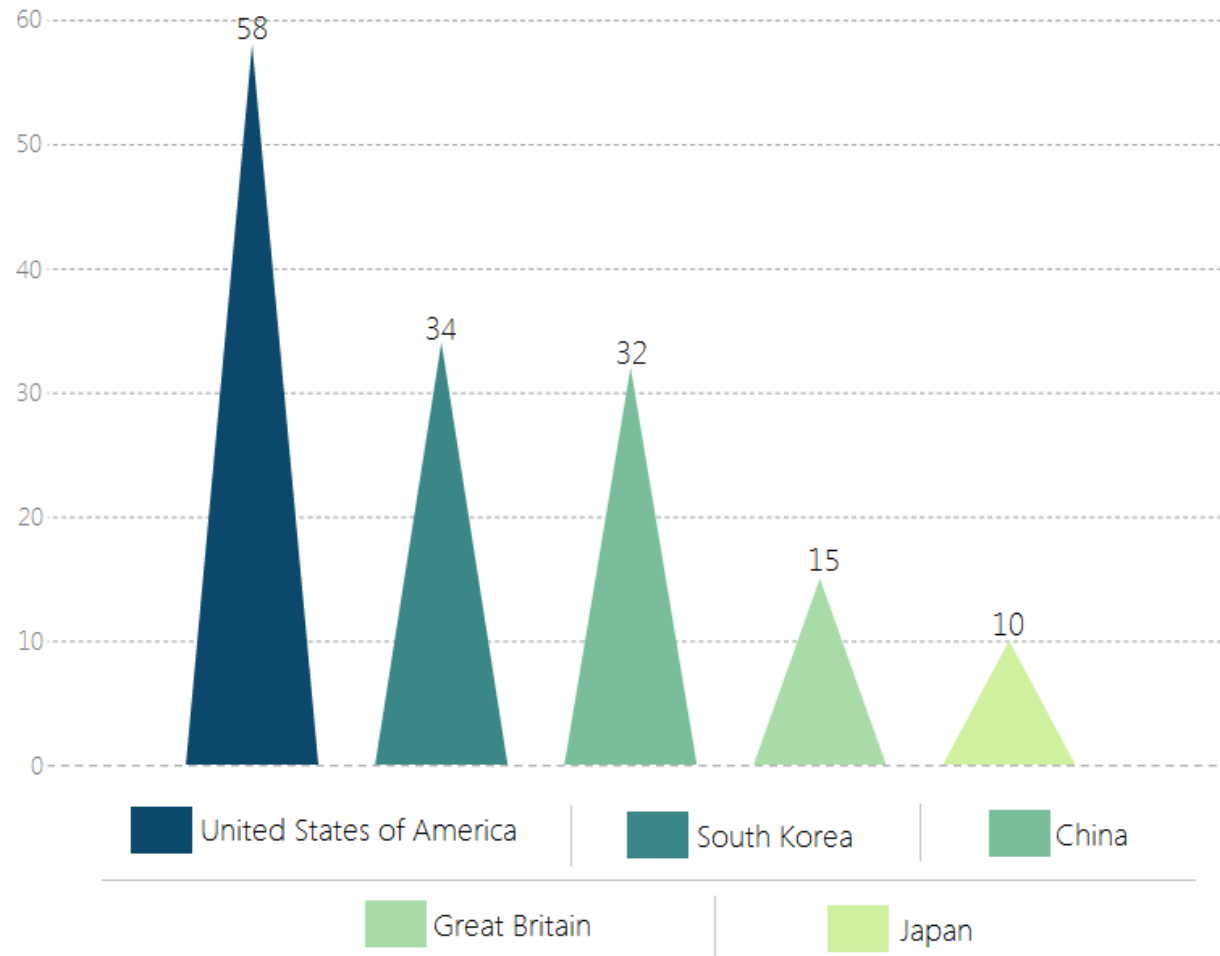– The **802.15.7m** is primarily looking at developing the existing 802.15.7 standard for visible light communications to include optical camera communications (OCC) and low rate photo diode communications

The IEEE 802.15.7 is a high-speed, bidirectional and fully networked wireless communication technology based standard similar to Wi-Fi's IEEE 802.11.

– The **802.15.13** is looking at using OWC for high speed specialty wireless networks for deployment in factories and industrial scenarios

leducation.org

IP*

Top Countries that filed patents in Li-Fi technology in past 10 years

- United States of America: 58
- South Korea: 34
- China: 32
- Great Britain: 15
- Japan: 10

V2V

- Demonstrated at 2019 CES
- Today's Lidar, Radar, and Cameras are reactive
  - LiFi will be predictive
  - Platooning
    - Virtually connecting 2 or more trucks
    - Reduces air hitting following trucks
    - Increase truck gas mileage by 30%

Stop Signs?

Opportunities

- LiFi Reduces commoditization of luminaires
  - Opportunity for Upsell
- Makes P.O.E. more viable
- Immediate opportunities for retrofit at museums, retailers, car dealers, etc.

LiFi Awards

- CES (2) 2018
- LIGHTFAIR 2018
- IES Progress Report 2018

This concludes The American Institute of Architects Continuing Education Systems Course

2019 LiFi Speaking Engagements

Reno
17 APR

Philadelphia
21 & 22 MAY

Paris
12 JUN

leducation.org