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In-House Light Paths Network Architecture

<- Ti-Fi -> draft version 15

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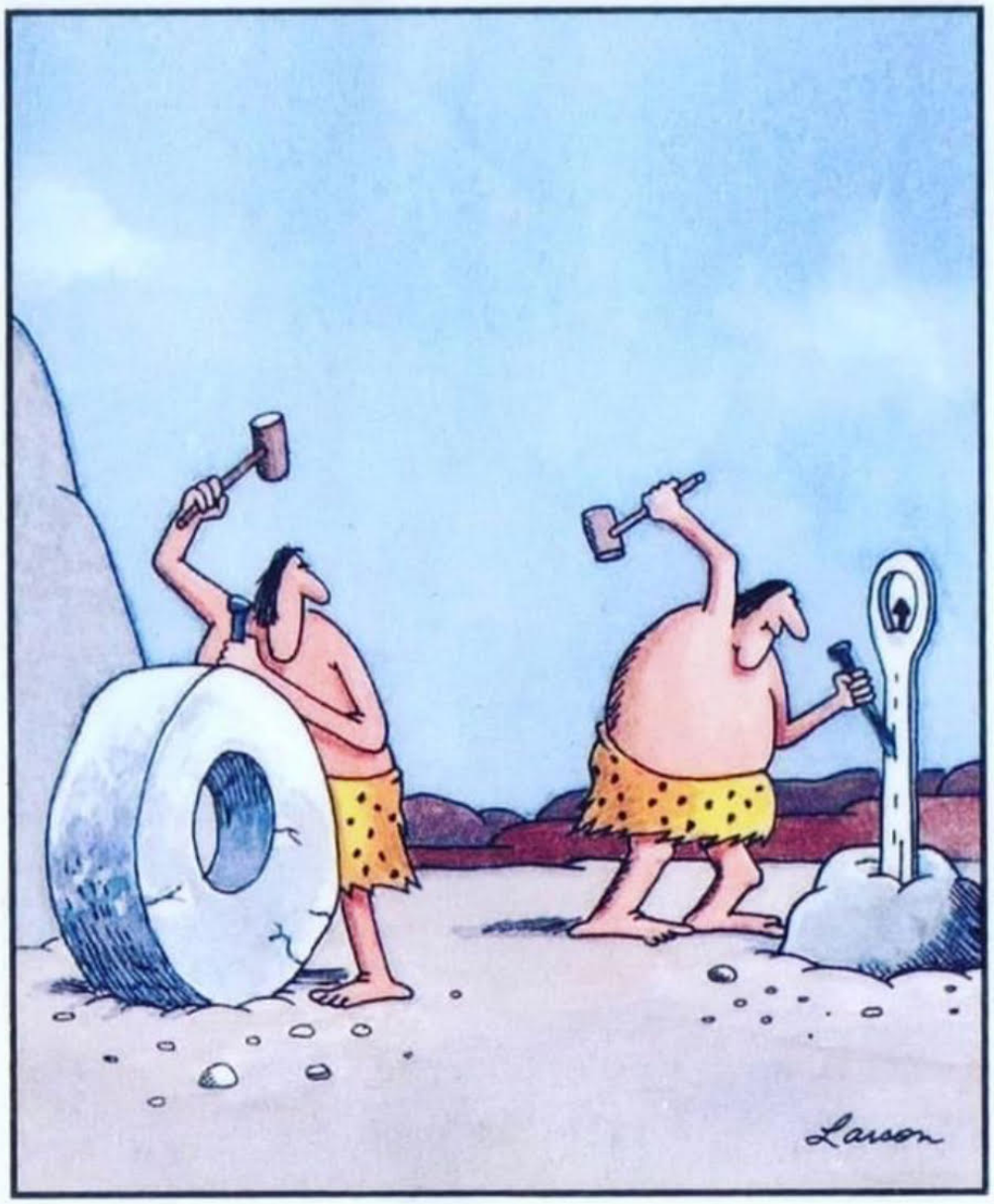
Dedicated to: Victor (Vic) Hayes and
Cees Links [Wi-Fi], Jaap Haartsen [Bluetooth]


Larson

1. Summary

This lecture presents a new architecture for indoor interconnection of mobile user-devices: laptops, smartphones, tablets; using a combination of plastic optic fiber (POF) cables in buildings and self healing smart mesh lightpaths in each room or office. In this way the devices can each be connected with 1 to 10 Gb/s symmetric IP links to eachother and to FttH/FttB Wide Area Networks. This architecture is future proof (upscalable) and can function as successor to inhouse Wi-Fi or inhouse 4G/5G, which are running into a number of limitations.

In other words, the Ti-Fi architecture can be described as “Wi-Fi with Light”.

What can be achieved is for instance communication between server farms, in cloud services of data centers, all the way to/from the mentioned user devices, almost completely with photon streams, instead of electrons. This agrees with the long time trend in digital infrastructures to replace electronics with photonics.

This new inhouse digital infrastructure is tailored to requirements of the customer side which are driving the demand for connectivity all over the world. Wi-Fi 6, 4G, 5G and even 6G had to segment design & implementation into diverse specific environments like factories, vehicle traffic, medicine, stadiums. For the presented architecture we have a) extended the requirements to what hundreds of millions of people would like/ demand in environments b) restricted to **rooms** in homes and rooms in offices. This is in fact the mainstream growth area for mobile computer network use. In practice 80% of that use is ‘**nomadic**’, meaning at a number of places/desks people use for instance internet access **stationary** (not moving) for a certain amount of time and then move to other stationary places in the building/ campus or go visit other companies, or go home, and sit down there with better online access.

(continued)

Summary, part 2

The Ti-Fi architecture does employ Li-Fi components (bidirectional infrared light beams) but not vertical from the ceiling or beam steered, but horizontal above the heads of the users to/from Ti-Fi devices at the walls connected with POF cables through plastic tubes installed in buildings/homes for AC power cables.

At the user side a simple Ti-Fi omni directional lightbeam/sensor device is connected with USB-C cable for power& signals to/from the user device. Enclosed in the room/office a mesh of lightpaths is set up by an App, with store & forward. In this way we make use of the fact that light beams can NOT penetrate walls. So there is no interference/electrosmog inside or outside the buildings. This mesh setup can be kept simple since only a limited amount of fixed positions (seats) are available in a room/office. The aim of this architecture is to make it robust and very low cost and DIY so implementation can take off into a volume market and at the same time unplugging the obstacles in the homes and offices for high speed network and ICT/ Cloud services use.

What is presented is in essence a kind of T-Ford (1908), the first affordable mass prduced car, for our data highways. Hence the name Ti-Fi. Yes it is a construction that has all the attributes (DIY)of a disruptive technology and it can be made to evolve and excite other innovations in society.

In the lecture we focus also on the real driver for the huge growth in bandwidth demand: computer-computer communication is bursty, self-similar with fractal volume sizes that have to be transported. In fact this has all the attributes of traffic on a **BUS** (computer backplane). This explains the popularity of Ethernet–like (level-2)/USB protocols on (optic fiber cable) digital infrastructures and at the same time forecasts the upper bound of needed bandwidth capacity speeds : the speed inside the CPU's and GPUs and inside the backplanes of for instance the laptops must be extended in the building and longdistance to the computers in de datacenters. Multi GigaBit/second streams for computers Apps that do not want to wait, but bombard the network with demands for data. An ancient saying applies here: "As Within so Without".

The Apple "Airport Base Station" (2001) was a big gamble of Steve Jobs but it helped launch Wi-Fi into massive mainstream use. And it did wonders for Mac sales. Our guess is that Ti-Fi's will launch the sales of Li-Fi links and photonics equipment in a number of positive ways.

2. Contents

3. What are the problems: *Stability, Coverage, speed? Short term remedies wifi: boosters, mesh network boxes*

- On the **customer side:** simply put, after *Gas, Water, Electricity* people expect well working *Wi-Fi* everywhere they are. But that is clearly not the case. It is not robust, not functioning all the time, not in every room or office.
- The indoor "digital infrastructure", due to its succes during Covid lockdown (Teleworking, Teleschool) is reaching its limitations. 4G, Wi-Fi is getting bad, jittery, due to density: too many people in the house (H2O frequency) absorb; edge oscillations when field is not strong enough.
- Spectrum congestion. See report and lecture of the NL frequency quality supervisor and regulator [2]]
- Exponential growth in numbers of devices as well as demand for capacity (streaming video, bigger files).
- Speed (bits/s) also known as "bandwidth" = link capacity is not adequate anymore, however 4G, 5G and Wi-Fi speeds can not be scaled up anymore, see next slide. In for instance USA and Germany the f.o. wired and wireless backbones are years behind NL, so they may not even have noticed yet, they will face a brick wall soon.
- For certain applications, like cloud computing, telemedicine and games, latency is getting longer, and what is worse: variable. This is negative too for Home Office transaction responsiveness.
- It is rather silly when Wide Area Network (WAN) connections are converging on 1 Gb/s or even 10/10 Gb/s to the premises, for instance with XGS-PON, that inhouse/indoors that sinks to for instance 10/1 Mb/s/ laptop.
- In responce to this "crowding" developers of network services had to resort to fragmentation into products for special applications & environments (i.e. 5G) : factories, PANS, IOThings, vehicles, agriculture, stadiums, emergency services (with slicing for priorities).
- Problem: Social-cultural obstacle-**Suppyside** lives in success of '70s: TV, Telephone, newspapers: ZOZ

Disadvantages: growing complexity, reflections,
protocol overhead (handover, errorcorrection)

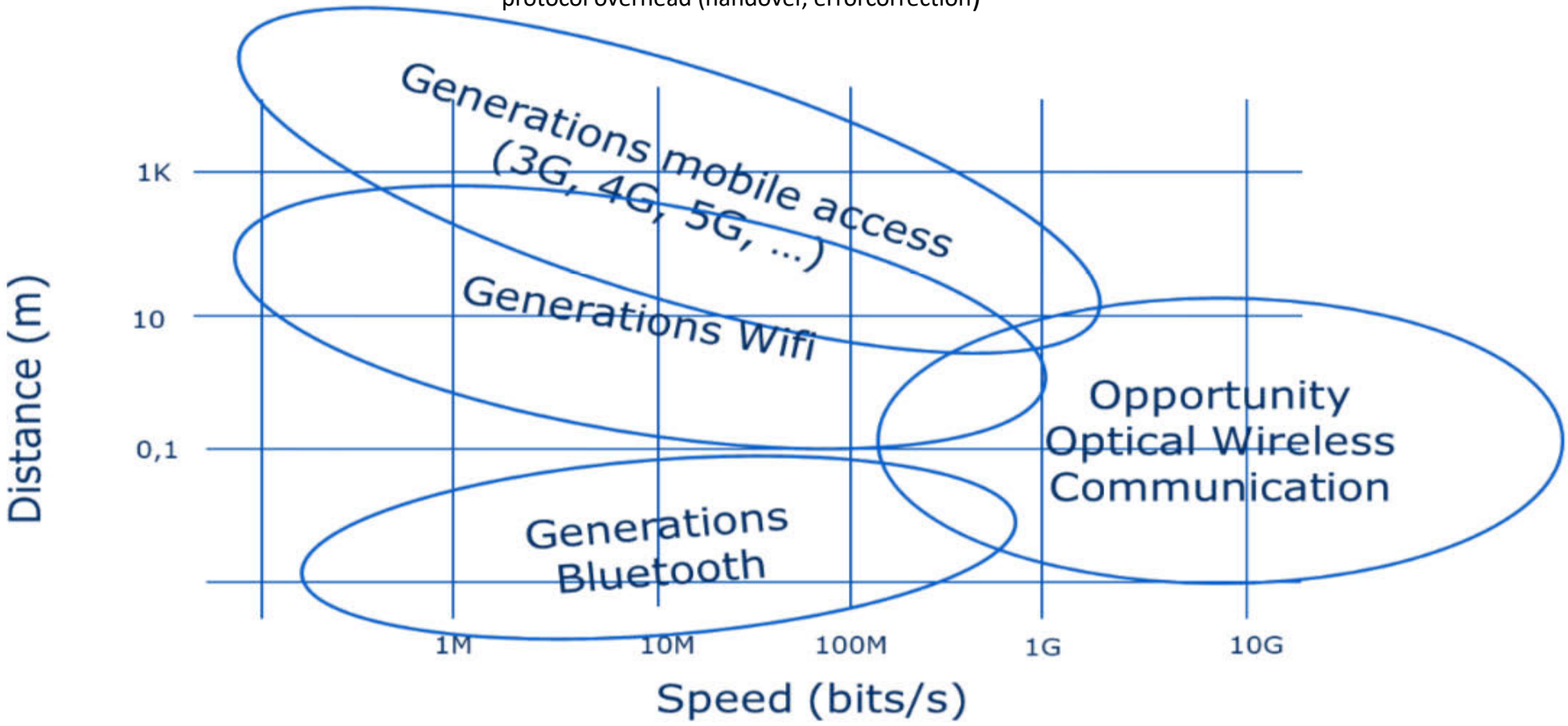


Fig. from [3] Positioning “Optical Wireless Communication” in Speed vs. Distance

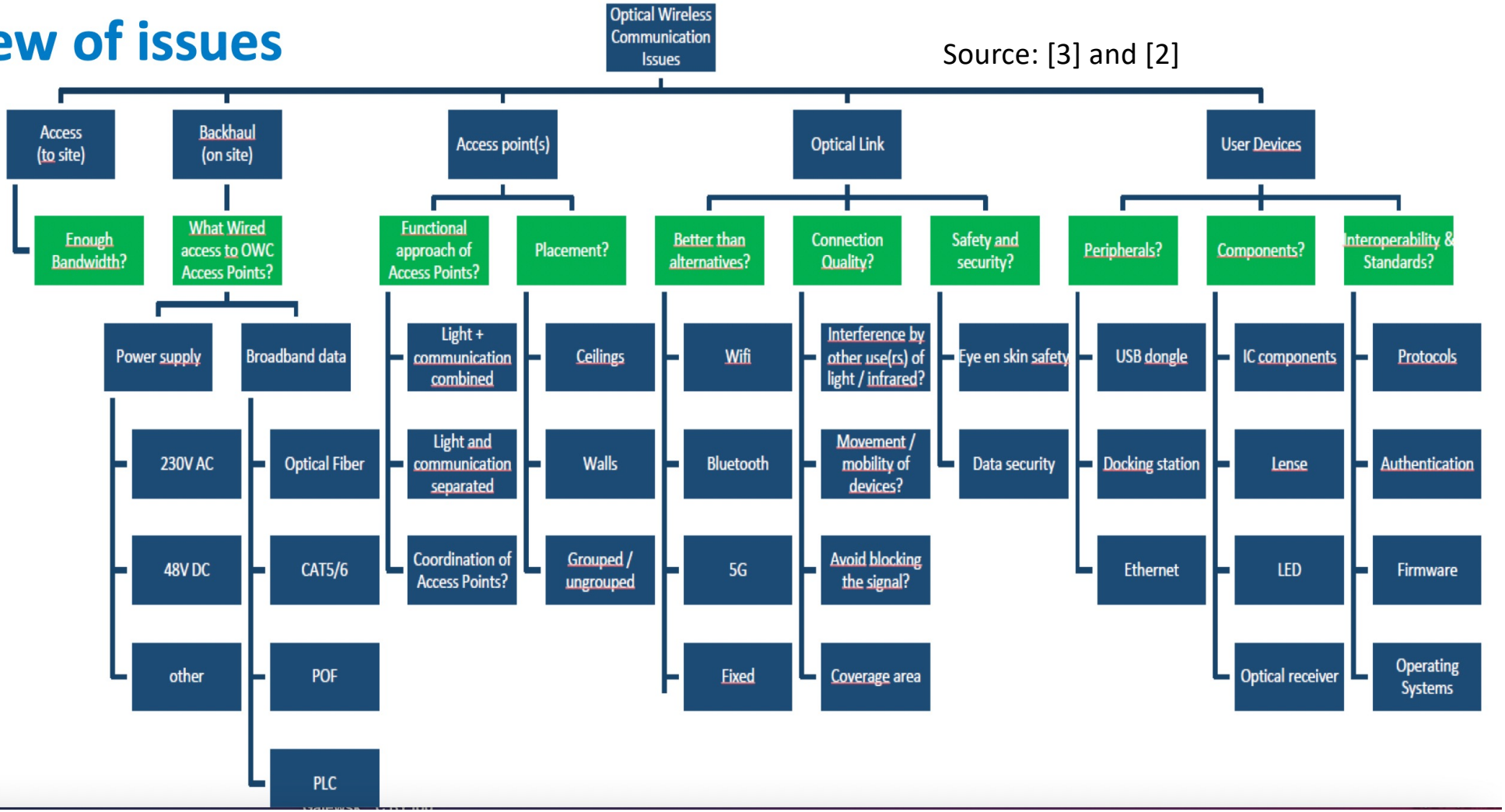
4. Approach to solve the in-house dilemma's,
with Optical Wireless Communication (OWC) as successor to Wi-Fi and G4,G5,G6..

4.1 Requirements

General overview See figure from [2] and [3] on the next sheet. "Issues"

Overview of issues

Source: [3] and [2]



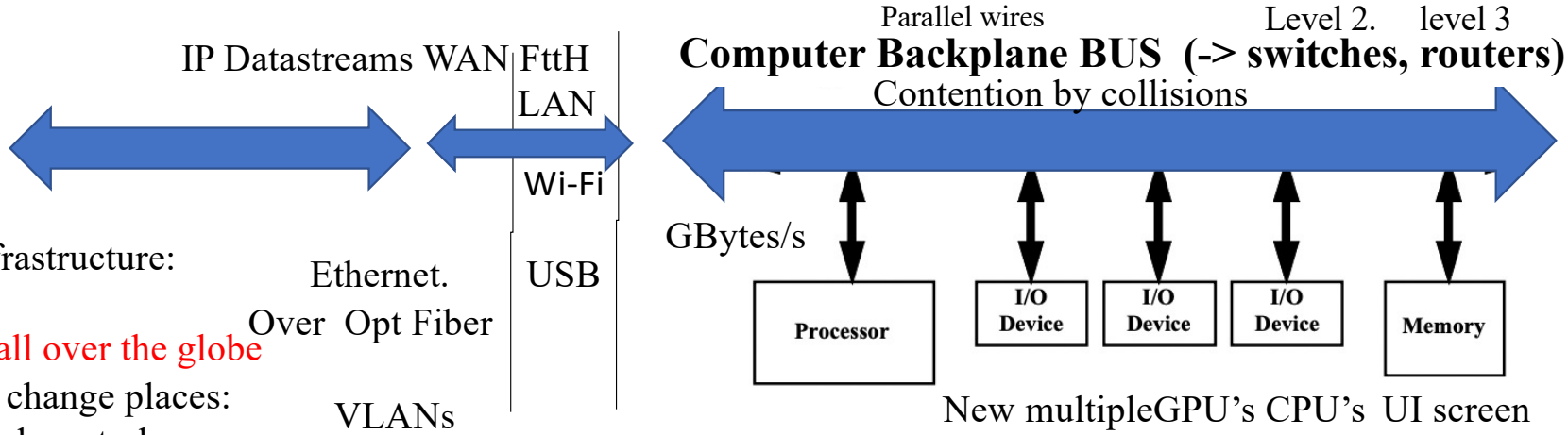
4. Approach to solve the dilemma's WOC

4.2 Requirements from the Customer/User side. VITAL: *Quality (**Reliability** of Internet connection) over **Price***
Modern existential FEAR: low battery power, low wirelesscoverage

- Robust. Especially for SME's connectivity internal as well as external is vital. They fear to lose connection.
  Extremely high availability (long MTBF, short MTTR, redundancy, spotting and removing SPOFs)
- Low Cost for installation and maintenance. Quality of Help Desks???
- Do It Yourself possibility (packages)
- Low Radiation (optic beam is also electro magnetic) ; no electro-smog. Regulators have declared IR and visible light links as "UnLicenced". No interference, No crosstalk.
- Low energy use, materials can be recycled. ----> Solar powered?
- Can grow into densely packed infra and scale up in performance. Estimates are a doubling in indoor capacity (exponential growth) every 16 months.
- Low and fixed latency
- 1 – 10 Gb/s symmetric connection PER DEVICE , with bursty, self similar (fractal sizes) IP datatraffic. *)
- Reduced complexity, user friendly, SAFE and confidential vs. Surveillance.
- Maintenance and measuring equipment. Addressing tools. Authentication with EduRoam/publicroam like tools.

4.2.1 *): Intermezzo. Where does the ever growing SPEED requirement per device come from? "The BUS Metaphor"

1972: Teletype computer terminal with modem dial up 110 b/s Full Duplex.
2021: 10 Gb/s USB power/signal cable for laptop = 100,000.000 times faster (10^8). Nielsen's Law: 50%/year ^ Why ?
(van Till: 100% ^ / 16 months)



Message Optic Fiber infrastructure:

- Wanted: Bus speeds all over the globe
- Functions can move/ change places:
  central -----edge ---- decentral
- Does not matter where !!! (latency?)
- Disintermediation ?! Example: PABX, analog telephony (Skype)
  Central Office switches. TV broadcasting.

- The real demanding clients are the billions
  of COMPUTERS !!!! They are the drivers.

- **Versatility:**
  - **New devices can be added easily**
  - **Peripherals can be moved between computer systems that use the same bus standard**
- **Low Cost:**
  - **A single set of wires is shared in multiple ways**

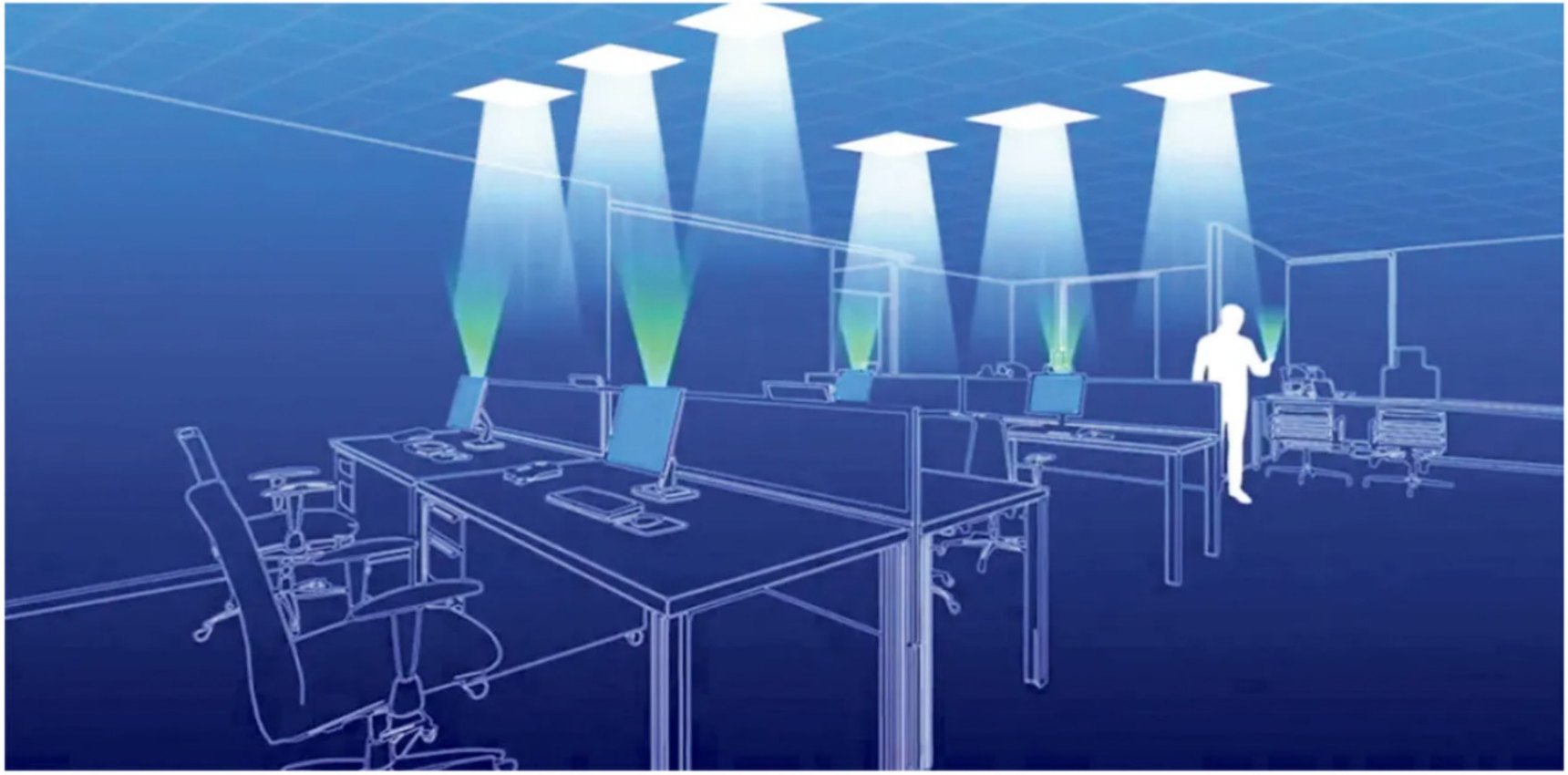
Mystics Slogan: "As Within, so Without"

4.3. Proposed solutions: Li-Fi vertical and Li-Fi with beamstearing

A. Internet from Lightsources (LEDs)= Li-Fi. Signify, part of former Philips Licht Divisie, is developing this. Source: [5].

B. Li-Fi with beamstearing from a corner of a room, developed from similar technique in 5G. Prof. Dominic O'Brian, Oxford

Both A and B are datatransmission links, not yet switched networks. And they have not yet reached economies of scale to take off.



5. The proposed "Ti-Fi Network Architecture"

In order to design an architecture which employs Wireless Optical Communication parts from LiFi, which can solve the stated problems of WiFi and 5G indoors; and which can scale up to reach huge numbers of users, we recommend to do the following moves:

(1) Extend the requirements & issues & demands (see 4.1) with the priorities of the customer/ user side (see 4.2).

(2) But to seriously decrease the complexity of the design, **limit** the scope and environment of the solution :

I ** *Environment*: Homes (including Homeoffices), Offices, boardrooms, multistory apartment buildings, farmhouse & barns, classrooms, libraries, laboratories, lecture halls, railway stations, airport lounges, student dorms.

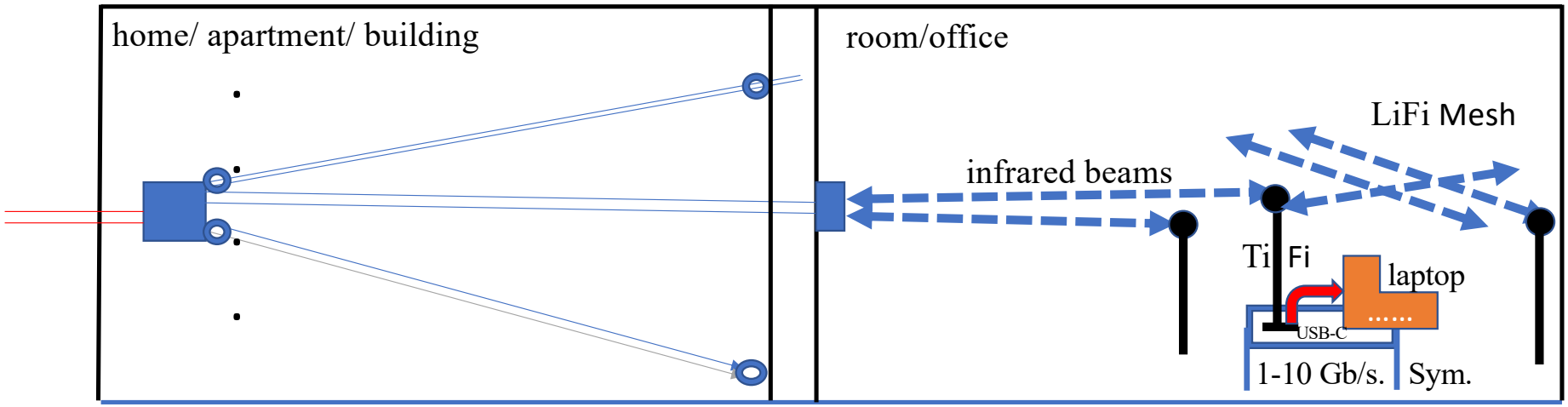
II ** *Personal Mobile "Devices"* = laptop computer, smartphone, tablet computer.

Please notice that I and II are not describing a market niche but consitute the mainstream of present day mobile devices use.

III ** *Type of use*: People on the move with their "device"; mobile but only NOMADIC = stationary for several minutes –to hours and then traveling without online connection. So **not** while driving, on bicycle, walking, in musea, in disco's, parks, beaches, on boats. That is where wifi and 4G/5G suffies. Please notice that Nomadic use (being stationary at work/studying) in several places during the day, is 80 % of all mobile device use !.

Please notice that these choices are in no way specific to race, shoe size or gender.

Structure of the indoors Ti-Fi Architecture



Components:

- External (FttH/FttB) interface to connect to multiGigabit capable services, enabled by XGS-PON technology, WAN on fiber optic cables. Compliant with ITU-T G.9807.1 specs
- Router/"modem", switching ethernet IP protocol streams
- Plastic Optic Fiber **(POF)** dual cables that can be pushed through existing electric wire 'yellow tubes' in homes and offices.**)
- 230V Wall contact connected to Ti-Fi room ditribution point. Above head horizontal IR Mesh with LED's.
- Ti-Fi (dongle) each with 6 bi-directional Li-Fi sender and recievers, for establishment of selfhealing MESH of IR lightpaths
- USB-C power &signal cable between Ti-Fi and tabletop nomadic device (laptop/smartphone/tablet)

- Ti-Fi Prototype 1

- Ti-Fi prototype 2

Work & study
undisturbed
at 1 -10 Gb/s

Rationale for choices of architecture components

- Plastic Optic Fiber cables (POF) **) Turns out to be easily self installed and robust, see [5]. Brings the Gigabit streams by optics **through the walls** between rooms. No interference, no decrease in signal strenght. I recommended these cables since July 2018, see: https://theconnectivist.wordpress.com/2018/07/12/improved-in-house-wi-fi-by-using-plastic-optic-fibre-pof/. The specs of POF say up to 40 Gb/s, which have to be verified/ certified cables for the in-house in-building distances.
- In-room/office lightpath mesh is recommended since the number of seats in such a room is limited and fixed. So implementing and maintaining light links with some store and forward operation, under control of Apps in the devices should not be too complicated. Wireless Mesh networks are available for Wi-Fi improvements from for instance KPN and VodaphoneZiggo in NL. Open source Mesh protocols between wireless devices for Bluetooth/ WiFi are avaiable too, from for instance Briar, Co-funded by the NLNet Foundation. The optic path meshes are **contained within rooms** since the IR light can not penetrate walls. Protocol for the Apps can be relatively simple 3 step : exploration in 6 directions, secection, establishing bi-dir. link and updating map of Mesh. Mesh availability must be developed to be selfhealing, robust and available.
- Visiblelight and Infrared (IR) communcation has been declared as unlicenced parts of the E.M. spectrum, since that spectrum is huge and not scarce. In this architecture we choose to use IR lightpaths horizontal above heads of seated users; of low intensity beams for the relatively short distances in rooms/offices
- Ti-Fi network access: password and device authentication (distributed) with EduRoam and/or GovRoam/ PubliRoam.

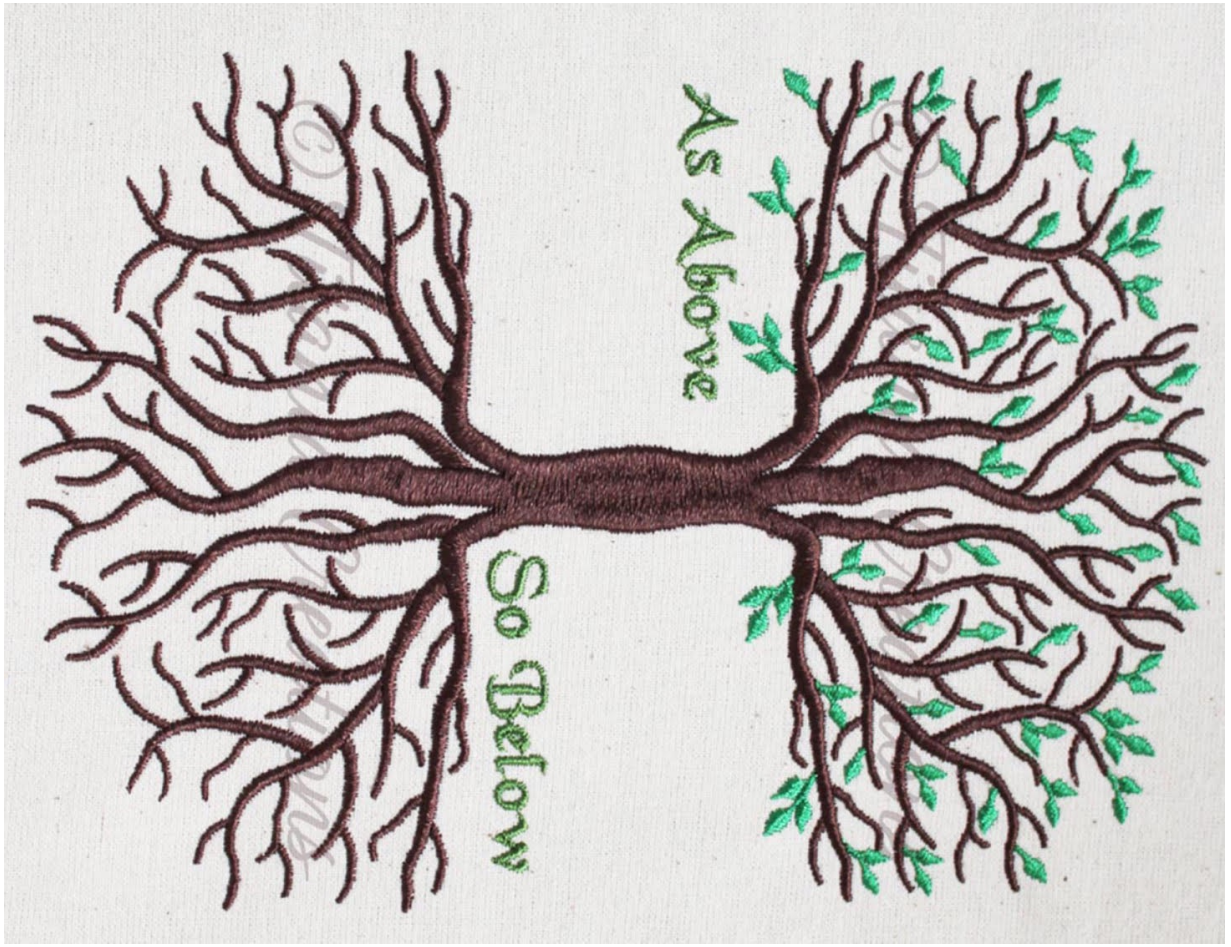
6. For future research

- Elimination of SPOFs. Parallel optical paths. Optic Router(s).
- In-room Mesh Prototype Fieldtests & Trials in Dormitories. Experiments by SURFnet.
- Establishment of a “Ti-Fi Hobby Club”, supporting prototype building and installations. Similar to HCC-NL
- Hollow Fiber? Instead of plastic? Hollow POF?
- Infrared levels and health hazards (eyes).
- Establishment of {Ti-Fi architecture, protocols & interfaces} compliancy office, with certification.
- Process of improvements, signified by versions.
- Development of Ti-Fi digital infrastructure towards HoloChain distributed applications.
- Can connect and have synergy with GAIA-X transnational Cloud services.
- Platform for high speed and constant latency gaming.

7. Proposed actions

- Pilot projects.
- I hope this architecture and these actions can help to start up a process of improvements in the public digital infrastructure, including in the indoors ones, so it gives people more Freedom to Create Value together (~ N !)

Inside
Data Centers



Inside rooms: meshes
Mobile Workstations

8. Sources

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