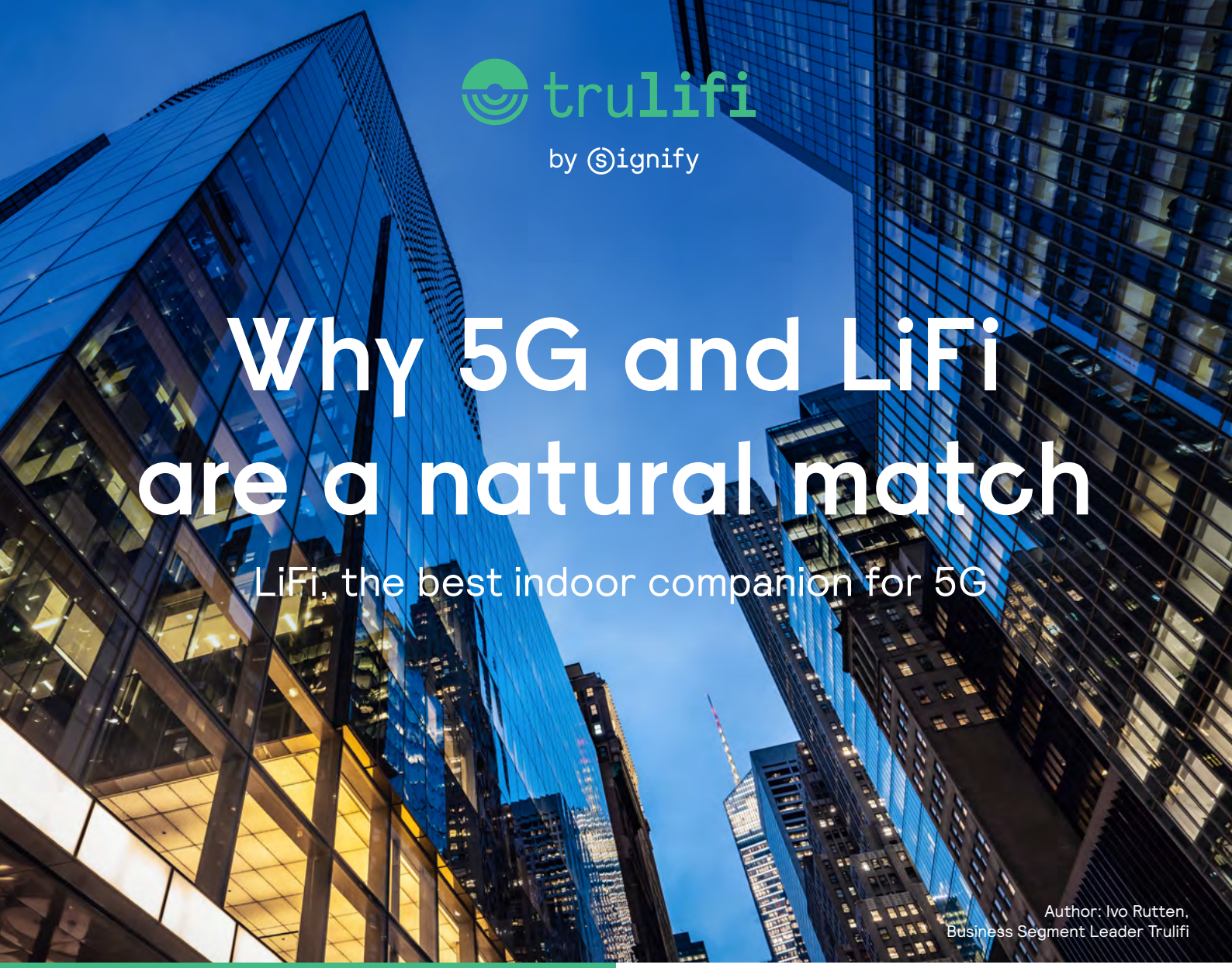

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Why 5G and LiFi are a natural match

LiFi, the best indoor companion for 5G

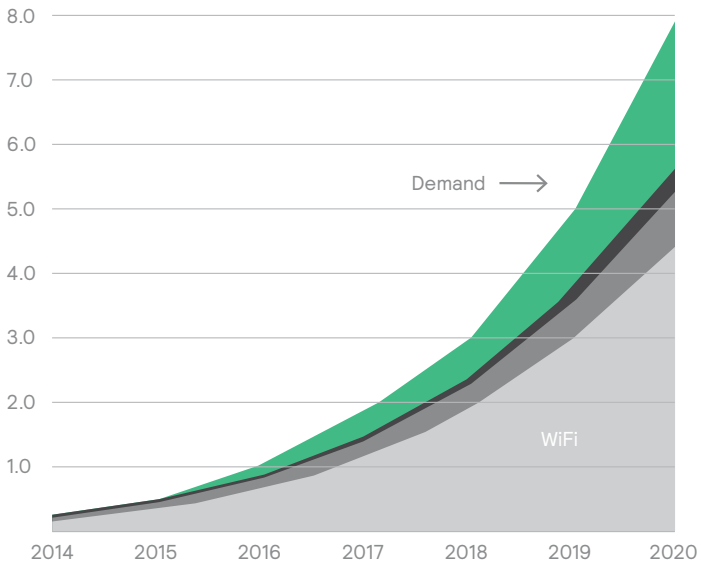
Author: Ivo Rutten,
Business Segment Leader Trulifi

The world as we know it

It is the world as we all know it by now: worldwide, internet data traffic is doubling every 18 months and much, if not most of this data at some point passes through a wireless network[1].

[1] According to a Bell Labs study, roughly 5 Exabytes/day are transferred via wireless networks. The same study estimates an additional wireless capacity demand of roughly 1 Exabyte/day. https://readymag.com/BellLabs/480968/

Exabytes per day



Source: Bell Labs Consulting

1.47 Unmet Demand

0.17 New technologies and alternate business models

0.93 3G + LTE and small cells

Telecom operators are talking about how they will be dealing with this data torrent by implementing 5G. While WiFi protagonists – already struggling with spectrum overcrowding – are explaining they are getting new frequencies, and how they are beefing up WiFi 6 standards to make more efficient use of the limited spectrum they are allowed to use (along with increasing numbers of other users of the same scarce unlicensed spectrum).

The battle for the indoors

Since the 5G spectrum is licensed for a hefty fee, licensees are trying to make the most of it. Unfortunately, many of their paying customers are spending much time inside, and 5G signals do not get into buildings as well as 4G signals do. Customers indoors – more so with 5G than with 4G – will therefore tend to be on indoor networks. This is the reason why 5G operators are attempting to expand their traditional outdoor deployment territory to inside offices, homes and factories, where 5G encounters a formidable incumbent in WiFi.

This paper points out that:

- As an indoor 5G companion, WiFi is not a fantastic fit;
- An upcoming technology, LiFi, offers a much better performance-fit to 5G, while offering a veritable Plenitude of empty data highway, as well as several other advantages.

The contest for the indoor customer is giving rise to many publications from each camp. One side is exploiting WiFi's inability to bring the same performance and reliable connectivity indoors as 5G offers outdoors. The other is countering that WiFi – and especially its latest incarnation WiFi 6E – will firmly be the indoor king and is promising better performance in the future than it has in the past (i.e. near 5G performance).

Usually the (sensible) conclusion is that both technologies will co-exist and that, while the battle for the indoor arena may lead to some small shifts, an outright revolution seems not to be at hand. The fact is that 5G is a fantastic innovation that particularly excels outdoors, when connecting wireless devices to backhaul and then to distant contacts. It is not very good at penetrating buildings with its signals, so would have to penetrate them with costly hardware instead. This is tedious, and comparatively expensive, also because the spectrum license fees need to be recovered. Moreover, users have to be comfortable allowing a third-party operator to handle their most private data[2].

Meanwhile, firmly established indoors, WiFi suffers from a shortage of spectrum, but at least it is a shortage of free spectrum.

The bottom line: 5G is great to deal with mobile outdoor wireless networking from anywhere to the backhaul and then onward to your doorstep, but after knocking on the door, it really benefits from an indoor companion.

The second part of the bottom line: WiFi is the legacy incumbent of indoor wireless networking but will very soon suffer from spectrum crowding again. The extra allocated spectrum and even benefits of clever new technology will be absorbed in no time by the data torrent that is thundering towards us.

[2] Of course, one can opt for a private radio network, but this is a seriously expensive option for hardware reasons and also because you need to foot the bill for a chunk of spectrum all by yourself.

What is LiFi?

In a nutshell, LiFi is a fast, high-throughput, stable, inherently secure (at the physical level!), less than 1 ms-latency, wireless connectivity technology, which is physically immune to electromagnetic interference, while itself not producing any electro smog. Its secret is to implement data transmission in the license-free light spectrum instead of using RF and millimeter waves (MMW) that are subject to a stringent regulatory framework. LiFi is novel[3], innovative, and at the beginning of its life cycle. The first commercial products already exist.

It goes beyond the purpose of this paper to explain all of the details of LiFi's workings, but here are some sources of information:

https://lifireport.com/

http://lightcommunications.org/

https://www.signify.com/global/innovation/trulifi

5G promises many welcome improvements

5G is not 'new' in the same sense as trading in your mid-class, run-of-the-mill sedan for a new, bright-red supercar. 5G rather builds an extra layer of very clever technology on top of parts of existing 4G networks. In this way it is more like giving the grey sedan a new paint job, new rims, turbos and superchargers, and adding the MMW realm to its navigation system. It is important to realize this, since it means that 5G brings a big improvement when it comes to data throughput, but it is still a compromise here and there where the old parts remain. We'll address some of those later.

Having said that, 5G offers many good new things. It promises a more stable, lower latency and more reliable network. It offers substantially higher data throughput, and its greater density of smaller cells can handle many more connected devices... it had better, since it has to absorb the data torrent somewhere. Moreover, 5G's many small cells offer optimized options to connect (large numbers of) IoT devices per square mile, which enables it to support the digitalization of industries (think of tracking goods in transit, as an example).

Its data throughput capabilities make 5G suitable as a kind of 'wireless fiber'[4] to the doorstep. Its low latency[5] allows new applications, including support of autonomous driving or remote control of delicate operations.

[3] Actually, that is not entirely true: it is not new to use light for data transmission. Alexander Graham Bell used it to such ends and got a patent before Guglielmo Marconi used radio waves. What is new is that there are now viable commercial products implementing high-speed, stable and reliable data communication using infrared light.

[4] If one owns actual fiber to the actual doorstep it makes little sense to use 5G instead, but using 5G technology to bridge the last part of the last mile from the end of the glass fiber 'trunk' to the actual doorstep is something that enables companies that do not own finely branched-out fiber networks in residential and commercial areas to still compete in delivering broadband to actual doorsteps.

[5] ~30 ms and dropping, which is 20 ms better than 4G averages; numbers based on practical implementation by Verizon https://www.verizon.com/about/our-company/5g/5g-latency

Security is improved too, and a much-marketed feature is network slicing: the possibility to split off a portion of the network capacity and dedicate it to a particular purpose (e.g. autonomous vehicle support) or customer (e.g. emergency services). Not only does slicing offer new business models to the network operator, it also allows increased security where needed (customized protocols within a slice).

5G offers these improvements particularly masterfully in the open space, where there are many users to connect and to chip in for the cost of the spectrum and the hardware.

But 5G has its drawbacks

Like any technology, 5G has weaknesses. Predicting the propagation of radio waves is not a simple profession, and the higher the frequencies the more difficulties the waves have to 'wash around' objects such as buildings, vehicles, warehouse racks and even filing cabinets. 5G's spectrum is at higher frequencies than previous telecom-designated frequencies, so this issue is aggravated. Some of 5G's allocated spectrum is above 20 GHz, and at these frequencies unimpeded wave propagation is certainly not a given. Even a glass window, particularly if treated with metal-based compounds to reflect heat, can be a roadblock for the 5G waves[6,7]. To guarantee sufficient coverage outdoors, highly skilled engineers tediously make radio plans, carefully positioning and tuning the 5G base stations to achieve acceptable signal strengths in all or most places.

Indoors, assuming 5G gets indoors in the first place, it is even harder to get reliable coverage, as metal structures, dynamic layouts in buildings, more or fewer people in the space, etc. affect propagation, and disturb reliability and speed of connectivity. Adding 5G hardware indoors gets the signals into a building, but not to improve their propagation through the building. 5G's claim to enable digitalization of industry is therefore more contentious inside than outside a factory building. This gets worse, since besides the normal indoor woes, in a factory or warehouse there tend to be more metal structures, sometimes mobile, and often there is a lot of electromagnetic interference (think of welding robots in a car factory). Radio-based wireless connectivity in an indoor industrial environment is very difficult to guarantee, also for 5G.

WiFi is radio-based, too, and has similar issues, but on top has the spectrum crowding problem. If 5G is promoted over WiFi for indoor use, it is because it can claim that particular problem does not affect it (at this moment), but all the other ones do. The relative 5G benefit comes at higher cost though: more expensive hardware, rampant IP license fees[8] and paid-for spectrum are the causes.

"How about security?", one may ask. "Is that not better with 5G than it is with WiFi?". To an extent perhaps it is, but as we said before, 5G is the sedan with the new paint job; many parts of the old car are still in there and they are less secure. Wired's Lilly Hay Newman wrote in December 2019[9] that 5G networks still leave parts of the data exchange unencrypted and vulnerable to fake base station attacks with so-called "stingrays" that trick target devices into thinking they are connecting to a cell tower. Also "downgrade" attacks are still conceivable in which a target's phone connection is manipulated to downgrade to 3G or 4G service, allowing hackers to use unresolved flaws in those older networks to carry out attacks.

All in all, 5G's ambition to dent WiFi's indoor hegemony is not a slam dunk, and it's my expectation that it will continue to need an indoor companion.

[6] https://www.rcrwireless.com/20180206/5g/5g-and-getting-through-low-e-glass-tag6 In this article the problem of penetrating certain types of glass is addressed with a technical solution.... so there is hope it seems, but it takes a lot of effort to get your waves into a building.

[7] WiFi 6 utilizes 6 GHz as a frequency. At 6 GHz the first propagation problems with 'objects of indoor size' start to become noticeable, which somewhat reduces the delight about this extra unlicensed spectrum for WiFi, as it aggravates the challenge of the radio planning for a network.

[8] WiFi is not free of IP license burdens either but the telecom industry takes the biscuit when it comes to IP license cost.

[9] https://www.wired.com/story/5g-more-secure-4g-except-when-not/

WiFi is not a great indoor companion for 5G, though

For those lucky ones who don't experience any immediate problems with WiFi, there seems to be no compelling technological advantage to replace WiFi if they already have invested in WiFi 5. However, enterprises better look ahead before they invest in WiFi 6 to cope with the growing data torrent. The expected exponential growth of devices and objects that will connect via WiFi will mean that even new spectrum and new WiFi 6 technologies will be running out of steam. WiFi 6 may be faster, more robust, and able to support an increasing number of WiFi devices simultaneously, but if data volume doubles every 18 months, any relief provided by WiFi 6 may be short-lived.

This is nothing but *deja vu:* we have seen WiFi expand from 2.4 GHz in 1997, adding 5 GHz in 2013 and 900 MHz in 2016[10] for 802.11ah with better indoor wave propagation. The most recently added data alley is at 6 GHz. Each time, the data volume outgrows the newly conquered territory in a shorter period of time, resulting periodically in overcrowded spectrum, and the inability to maintain reliable network connectivity.

Scraping the barrel for more bits of spectrum is not going to cut it for much longer: something else will be needed with more headroom, if nothing else to help offload the poor WiFi camel that is carrying ballooning bales of straw.

Not only will the WiFi network have to transport much more data, the IoT megatrend entails a connected device explosion, which will put another strain on the infrastructure: more connected devices raise the noise floor in the spectrum, like in a busy pub you can't always hear what someone says to you.

This lowers throughput, since the fuller the pub, the more punchlines need to be repeated. Latency increases too, and fluctuates, since the information arrives only after having been repeated (a few times). Many of these noise-adding IoT devices will not require a lot of bandwidth, but they still need a decent quality of service level and the reliability of an infrastructure-sans-crashes.

When asked, people often say WiFi functions 'OK', but if you drill down you discover that there are actually many complaints that people have learned to live with[11]. Very demanding users[12], such as serious gamers, often give up on WiFi altogether and rely on a wired connection instead. Even if WiFi functions 'OK' today, it stands to reason that it may drown in data somewhere in the (near?) future.

With that in mind, perhaps it is now the time to think of a revolutionary, rather than an evolutionary innovation of your wireless indoor network.

[10] http://www.iosrjournals.org/iosr-jce/papers/Vol17-issue5/Version-3/D017532629.pdf

[11] The majority of Signify-conducted customer interviews of WiFi users showed this pattern. Users were first asked how their WiFi was performing. Some people immediately pointed out issues, but the ones that did not, when asked to explain how they used WiFi and what for, almost invariably started to come up with anecdotes of how WiFi did let them down at times. Interestingly, these were not random events but things that repeatedly caused trouble (e.g. 'it works on my side of the bed but not his'). Remarkably, people seem to find workarounds, and push these issues under some threshold of observation. Maybe you do that too?

[12] 'Demanding' here usually comes down to a need for low and stable latency even more than for data throughput rates.

LiFi, the revolutionary innovation of your indoor wireless network

We have established that 5G is offering great improvements, and that these are greater with an indoor companion. This indoor technology has to augment 5G, without adding bottlenecks that thwart 5G's newly established good features. This means we are looking for something that:

- Does not suffer from spectrum congestion;
- Offers guaranteed high speeds, always;
- Performs with latency as good as or better than 5G's;
- Is as secure as 5G's newly added layers, or better;
- Can naturally extend/augment 5G's network slices.

Ideally the revolutionary extension technology is even improving on 5G's indoor weaknesses, so it would need to be:

- Deployable and predictable without tedious radio planning;
- Immune to EMI and not itself electrically interfering with any other equipment;
- Fully compatible with existing IT systems, including WiFi, to allow continued use of earlier investments, while offloading the legacy systems;
- Easy to install;
- Maintainable in similar ways to existing indoor networks;
- Affordable in terms of hardware;
- Free from any spectrum license fees.

Too good to be true? No, it is not.

LiFi meets all of these demands and desires

Deploying LiFi as the next upgrade of existing indoor network extensions is the way to avoid the indoor weaknesses of 5G without in any way throttling back what 5G (or high-speed fiber, for that matter) delivers to your doorstep.

Signify's Trulifi already offers a choice of commercially available, worldwide certified products to make your next innovative step and be ready indoors for when 5G is happening outside.

Food for thought?
Feel free to pose your questions to
lifi.systems@signify.com

About the author:
After a long international career in Philips and Signify after its spin-off, Ivo Rutten recently joined Signify's Trulifi Business Unit. In the first decades of his career his focus was on (telecom) semiconductors and consumer electronics, and after he joined Philips Lighting/Signify as an executive in various roles. Ivo is an Executive Fellow at the Rotterdam School of Management, Erasmus University, and holds a EE degree from Delft University of Technology and an MBA degree from Erasmus University and the University of Rochester, NY. His office is located in Eindhoven.

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