The Siren Call of Li-Fi
A Brighter Solution

Father of 'Li-Fi,' Prof. Harald Hass (*CSO of pureLiFi Ltd. and Professor at the University of Edinburgh*) coined the term to mean 'light fidelity' (*visible light communications (VLC) closely equivalent to Wi-Fi) However, Li-Fi is rather distinct in a far more fascinating approach; it is distinguished as new, ground-breaking technology which aims to provide ubiquitous wireless access for indoor communications, or indeed any, illuminated area.* Li-Fi uses the light waves from LED light bulbs to transmit data, simultaneously providing a home or area with both illumination *and* wireless communication.

With the demand for mobile wireless access ever growing, mobile cellular and Wi-Fi networks will continue to become increasingly congested—to a limit where adding additional radio frequency (RF) resources will be ineffective—this is referred to as the *spectrum crunch*. A brighter solution is manifesting; with over 70% of mobile traffic originating indoors, Li-Fi is ideally poised to resolve this spectrum crunch by supplying complementary (non-interfering) bandwidth in LED illuminated areas, and, its enormous data density capability will substantially reduce the burden on existing RF networks.

What Constitutes Li-Fi?

Li-Fi is well-defined as the *networked, mobile, high-speed* VLC solution for wireless communications. To facilitate pervasive indoor wireless access, each Li-Fi system requires:

- **High speed** – the exponential growth of wireless data demand is not only due to the growing number of users, but also the availability of high-rate downlink services, such as video streaming and file download—both of which require large amounts of bandwidth. Li-Fi systems, therefore, must be high-speed to maintain currently offered network services and user expectations.
- **Bi-directionality** – to provide modest Internet access, there must be a reverse link from the device to the network which allows the device to request and/or modify information—and in a large data crazed world—upload photos and videos. Thus, bi-directional communication is essential for full network operation and a user friendly experience.

- **Multiple Access** – for RF networks to serve an abundant volume of users, each cellular base station (BS) (*100's of mobile users*) and each Wi-Fi access point (AP) (*10's of user devices*) shares its time and/or frequency resources among the connected parties. Given that a defined area, theoretically housing multiple users/devices, could be illuminated by a single luminaire, adding Li-Fi to the light will necessitate a similar sharing of resources. This is called **multiple access**, it is needed to extend wireless access to all desired users within the illuminated space, and hence the network.
- **Mobility/Handover** – finally, due to the inherent directionality of light (*as opposed to RF signals*), any space (*generally indoor, but also outdoor*) that is to be illuminated needs several light fixtures to sufficiently cover the area. Since in a Li-Fi network every light source is a wireless AP, it is essential for network operation that the communications link is unbroken while a user is moving: the network must *hand-over* the user from one AP to the next. Without such functionality, a mobile user will need to constantly re-establish connection with each network AP, and *re-start* its running information transfer on the device.

While some of the above features are more important than others, all are fundamental to the operation of Li-Fi for wireless communications networks. Each contributes for less disturbance and difficulty and influences higher efficiency with an overall improved user experience.

The Dangers of '*quasi*-Li-Fi'

Even in its early period there are already a few commercial Li-Fi products available. As an emerging technology, developing Li-Fi products will have very limited capabilities.

The lure – the siren call if you will - is that "first mover advantage" harbors many pitfalls for all but a few well defined applications in specific market segments. Rushing to products (*i.e.*, missing one or more of the core features) potentially dead-ends those products in a technological niche…

Bi-directionality is, perhaps, the easiest feature of Li-Fi to overlook. However, that would essentially eliminate the possibility for a true Li-Fi system. With broadcast-only technology, the system is limited to just offloading the RF network downlink, and an uplink connection must be established else-wise. This leaves the product applicable to only a handful of use cases (*e.g.*, sensor networks, *data showers*). If **high-speed** communication is disregarded, the Li-Fi network degrades to a basic

control information distributor, which may enable a few applications such as: indoor positioning and mobile app content update. Moreover, the network will be reliant on existing RF infrastructures for content delivery and will in fact accelerate the inevitable spectrum crunch.

In order to serve the high extent of indoor users requesting traffic, each Li-Fi AP must be able to provide **multiple-access** to facilitate multiple users. It is lucidly infeasible to establish a dedicated point-to-point link for each person in an indoor space, as in today's modern world almost everyone owns a mobile device. Thus, the lack of multiple access capabilities diminishes the applicability of the product to merely point-to-point communications where current wired, RF, and laser technologies are deemed unsuitable. Such application areas include underwater communications, some sensor networks, and hospital patient monitoring. Yet, even in these areas the ability to communicate with many devices would greatly enhance the product functionality.

Finally, the principal requirement to achieving ubiquitous wireless access is the ability for a mobile device to transfer from one AP to another without its connection faltering, and its information transferal being interrupted. Imagine if, in an office space, a user is downloading important documents while moving around the room, and whenever he/she leaves the illumination of one luminaire and enters the next, the downloads need to be restarted. This eliminates the possibility of **mobile** wireless access, because the user is not being **handed-over** from one AP to the next. The result would be a static-user wireless access scheme. This denies the very ubiquity of wireless access that has become a part of everyday life, depriving the illuminated space of proper networked communication.

The Value of 'true' Li-Fi

Due to the immense challenges of developing a full Li-Fi system, it can be very easy to be drawn into the simpler solutions in an attempt to get to an early product and revenue. However, the development of a 'true' Li-Fi solution will provide vast benefits for the developing company, both in the short/medium term, and especially the long term. Among these benefits, the main are:

1. The elaboration of a 'true' Li-Fi solution will allow products to be derived from this solution that can be utilized in (almost) all VLC applications and use cases. 'True' Li-Fi is supremely competent to provide indoor communications. All other VLC offerings are only a small part of a 'true' Li-Fi system. Location-based services can be implemented through unidirectional, low-speed Li-Fi. Point-to-point applications (*e.g.*, underwater, transportation) can be achieved without the need for multiple access, and *Augmented Entertainment* for the television market can use non-networked Li-Fi. Therefore, during the development of full Li-Fi, not only can products be spun out for niche areas, but the final solution will allow the developer access to every aspect of the VLC market.

2. While there have been various markets identified for the proliferation of VLC/Li-Fi technology, the primary target market is indoor networked communications. The discovery that a substantial portion (> 70%) of wireless traffic originates indoors, identifies this environment as the place where Li-Fi will be indispensable in the future. The conception of a 'true' Li-Fi solution will preferably position the developer to command this market. The second largest area of interest is that of location-based services, which utilizes a unique method to deliver data to standard smartphones and tablets. By delivering precise positional information to users, retailers and service providers can transmit location-based advertising and messages to substantially enhance consumer interaction. Ultimately, as mentioned above, the 'true' Li-Fi solution allows the developer to dominate all market segments and establish themself as market leaders for VLC and Li-Fi solutions.

GLOBAL VLC MARKET REVENUE, BY APPLICATIONS, 2012 - 2018 ($MILLION)

Application	2012	2013	2014	2015	2016	2017	2018	CAGR% (2013-2018)
Intelligent traffic system	0.00	48.08	87.39	153.84	249.22	390.55	554.23	63.1
Indoor networking	83.66	213.60	486.00	1,012.80	2,040.00	3,300.00	4,577.00	84.6
In-flight entertainment and communication	0.00	6.54	12.48	21.81	35.52	55.28	84.70	66.9
Underwater communication	0.00	1.20	2.60	4.80	7.10	9.00	12.00	58.5
location based service	12.42	37.70	90.07	187.79	359.25	596.90	910.08	89.0
Total	96.08	307.12	678.54	1,381.04	2,691.08	4,351.72	6,138.02	82.0

Source: MarketsandMarkets Analysis

3. Dictating the VLC market through cutting-edge Li-Fi technology holds other values than just market share and revenue: principally, the power to drive and influence VLC standardization. The established Li-Fi market leader will have the unique position to develop a new standard that defines the operation of VLC for indoor communications and content delivery. By liaising with major handset and tablet manufacturers, the integration of Li-Fi technology into such devices can begin—with the market leader at the helm of this collaboration. All in all, the development of the 'true' Li-Fi solution will ultimately guarantee the developing company not only the market leadership, but also the continued strength to secure and bolden this position.

Conclusion

Li-Fi networks can, and will, provide the perfect complement to today's RF infrastructure and further enhance mobile communications. However, the lack of 'true Li-Fi' products can lead to limited application, that ultimately do not constitute Li-Fi (*as it has been defined*) solutions. The spectrum crunch is coming, and indoor communications will be in sore need of bolstering, given that the current rate of wireless data growth is unceasing. The only solution to this is a high-speed, bidirectional, fully mobile wireless network: a Li-Fi system.