Which LiFi's apps may fit mostly to 5G and beyond-5G Technology?

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***Abstract*—LiFi technologies are expected to be an integrated part of future broadband wireless technologies. However, it is still not fully clear which apps will fit and benefit future 5G and beyond-5G. The purpose of this paper is to retrieve through Analytic Hierarchy Process model (AHP) and qualitative analysis the most promising apps. Apps for homes, supermarket, museum, communication between vehicles, in-flight entertainment and hospitals were considered. Relevant criteria include latency, data security, data-rate per square-meter, number of customers in square meter and acceptance. The results indicate that acceptance criteria found to be most dominant and hospital driven 5G apps most promising.**

Keywords—LiFi; apps; 5G; beyond-5G; AHP

I. THE OVERALL PROPOSITION

We suggest an Analytic Hierarchy Process approach (AHP) [1] to let industrial companies, small medium enterprise (SME) and research institutes, focusing on LiFi needs to decide on their most favorable application in their long journey until the technology will be widely spread. According to a recent report of Market Research Future [2], the global LiFi market is expected to reach approx. USD 51 Billion by 2023, at 70% of Compound Annual Growth Rate (CAGR) between 2016 and 2023. Selecting the most favorable LiFi market segment related to 5G and beyond-5G (B5G) applications is of key interest. The need to examine several criteria and rank them systematically will let decision makers to focus on small number of variables.

AHP approach was further extended in [3] to a model that fits multiple complex criteria and decisions. The model divides the various parameters into pairs of criteria and compares each pair. At the time of decomposition, only two criteria are compared at a time, and then a comparison is made between two adjacent clusters in which a decision was made. This makes comparisons, analysis and treatment easier. We propose an analytic research, calibrated by TransparentChoice S/W [4], to address the complex decision problem. In addition, the experts had provided qualitative inputs. We have further investigated the correlation between the AHP model and qualitative analysis.

II. 5G-PPP KPIs

In order to build a decision tree based on the AHP model, a subset of key criteria was carefully chosen from the literature reviewed in [5], [6] and [7]. We target within this work the 3GPP Working Group SA1, which is responsible within 3GPP for services and feature requirements specification. European 5G-PPP Rel-15 [7] is considered 5G, where Rel-16 5G NR and later versions are considered B5G. Detailed key performance indicators (KPIs, i.e. criteria in AHP terminology) in 5G-PPP were analyzed in [8] including four performance, five societal and three business. Recommendations for refinements are suggested in [8].

TABLE I: 5G-PPP KPIs [7], [8]

	Performance KPIs
P1	Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
P2	Saving up to 90% of energy per service provided
P3	Reducing the average service creation time cycle from 90 hours to 90 minutes.
P4	Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.
P5	Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.
P6	Enabling advanced user-controlled privacy.
	Societal KPIs
S1	Enabling advanced User controlled privacy.
S2	Reduction of energy consumption per service up to 90% (as compared to 2010).
S3	European availability of a competitive industrial offer for 5G systems and technologies.
S4	Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications
S5	Establishment and availability of 5G skills development curricula

	Business KPIs
B1	Leverage effect of EU research and innovation funding in terms of private investment in R&D for 5G systems in the order of 5 to 10 times
B2	Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding
B3	Reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, the reported 2011 level of 43% global market share in communication infrastructure.

III. Methodology to Address Use Cases and KPIs for 5G Combined with LiFi

Specific examples of set of performance KPIs selected in various use cases for 5G combined with LiFi is described in [10],[11],[15] and [16] including:

1. Peak data rate (10Gpbs)
2. Peak Spectral efficiency (30bps/Hz down, 15pbs/Hz up)
3. Bandwidth (mmW 100MHz, VLC 10MHz)
4. Control plane latency (1 to 20ms)
5. User plane latency (down/up 4ms)
6. Latency for infrequent small packets (1 to 20ms)
7. Reliability
8. Coverage
9. Area traffic capacity ($50Mb/s/m^2$ - $1Gb/s/m^2$)
10. User experienced data rate (100Mbps - 5Gbps)
11. Connection density 4 - 40 $device/m^2$
12. Mobility (1m/s)

In this work, we consider having LiFi technologies as part of new spectrum for 5G/B5G and focus on the following subset of key criteria:

Latency (LAT**)** - The time it takes an information package to be sent from a source to a destination.

Data security (DS) - Immunity from quotation, and access to information.

Data rate per square meter (Drpsm) - The required data per square area, depending on the different information consumers.

Number of users per square meter - (Noupsm) in the market segment.

Acceptance - The willingness to adopt a new technology and understanding its benefits.

A. Apps Mapping: Current state of LiFi's apps Sugested for 5G and B5G and Technology Impact on app

LiFi market can be segmented based on following [2]: by applications, by components, and by end user. In this paper, we focus on apps tailored to main use cases considered in 5G. Seven key apps are analysed: Communications between Vehicles (CBV) [9], Home and in-building (HO) [10], [11]. Hospitals (HS) [12], In-Flight Entertainment (IFE) [13], Museum (MU) [14], Supermarket (SU) [15] and Underground Train (UT) [16].

CBV can further be subdivided into Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Network (V2N) and Vehicle-to-Pedestrian (V2P). HO can be subdivided into two groups: youth and adults. Usually, younger users are interested in on-line and interactive games; adults are using more cloud computing, smart home services etc. SU use case needs to provide location information for various product, nutrition facts, comparative cost and can serve as a key enabler for smart shopping.

UT/IFE users can be subdivided into two groups. Maintenance workers and passengers. The UT/IFE information will inform the passenger which way leading to the right dock. Airports app will divide into two groups: employees (maintenance teams), and passengers. Maintenance teams are required to perform various maintenance tasks including work and operating instructions, maintenance history, procedures, guidelines, instruction performance videos, location of required maintenance, and monitoring of all in real-time. LiFi technology will provide the medium for the transmission of this information. Moreover, the technology enables direct communication between the employees and the control center via video calls or conference and receiving feedback from the employee in real time. In addition, it is possible to receive real-time sensor alerts about fire, oxygen amount in the air, poisonous carbon monoxide and receiving status on the smoke detectors to the control center immediately in high reliability. Security guards will be able to use LiFi technology to transmit messages to the control center and to transfer requests to the security services if necessary. Through this technology can also record events in real time. For passengers, the technology will allow location, mapping and navigation within railway stations, docks / gates location, service stations, ticketing stands, services and restaurants. A passenger can download the ticket to the mobile device and transfer it at any point of payment and transit, as a substitute for the old system in which the passenger is required to produce a card and save it while traveling. In addition, the passenger can receive travel timings or notices of abnormal delays of train or airplane to the destination station in real time.

B. Limitations of Current Approaches to Select the most Favourable LiFi's apps

We will divide the barriers into two categories: barriers on the physical plane, and barriers in the perceptual plane.

A barrier on the physical plane: In most use cases, a line-of-sight (LOS) between the transmitter and the receiver is required. Without LOS, there may be information disruptions in LiFi reception. Using DCO-OFDM [17], LiFi for optical selective channels can be used, thus overcoming LOS limitation. The intensity of the LED lighting should have such illumination intensity that it is possible to reach the receiver and be decoded according to transmitted data. For this purpose, the LED needs to comply with the requirements.

In order to transmit the information, there is a need to change the infrastructure, rewire the communication lines to the LED units. This barrier is a physical plane barrier as well as a perceptual plane barrier.

The barriers on the conceptual plane: The problem of adopting new technologies that involve the customer's perception of the new technology and the understanding of added-value against the old technologies. This also called technology acceptance model (TAM) and first explored in [19]. The model explores perceived usefulness and perceived ease-of-use of a new information system.

IV. Semi-Structured Interview

A. *Apps and Decision Criteria*

In order to perform a qualitative analysis, a semi-structured interview with respect to the various app's and criteria was conducted. The collection of the data from the interviews was implemented in the form of recording and transcript to see the correlation of the information in order to learn and understand the significance of the data accepted in the quantitative model. The data analysis was carried consequently to contents that were implemented, in the number of main subjects that were identified according to the experts: advantages and disadvantages of the technology, adoption of the technology, data security of the information and the different needs in each application. Data analysis is based on keywords that were repeated or emphasized by the experts. This process was done by comparing the partial information in different variations in order to find similarity, differences and relation between them. Finally, we implement comparison matching between answers, interviews and AHP model comparison.

B. *Decision tree*

During the interviews, the experts were asked about the criteria that were chosen and gave their opinion to additional criteria. Because the information of having LiFi applications suited to 5G and B5G is limited, we picked experts in the field of LiFi communication. In the next stage, we built a decision tree based on the criteria chosen based on survey of the literature and opinion of the experts.

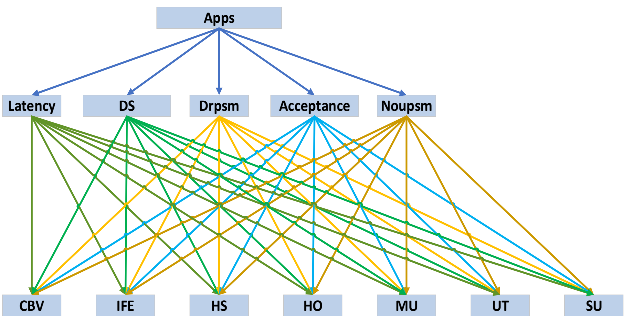

Fig. 1. Decision tree for selection most promisng LiFi app.

V. Comparison Between APPs and Criteria

Perform comparisons between each criterion and each pair of applications for each expert in accordance to AHP methodology. Presentation of the weights averaged over all the experts, as produced by TransparentChoice S/W [4], is shown in the Pie diagram of Fig. 2.

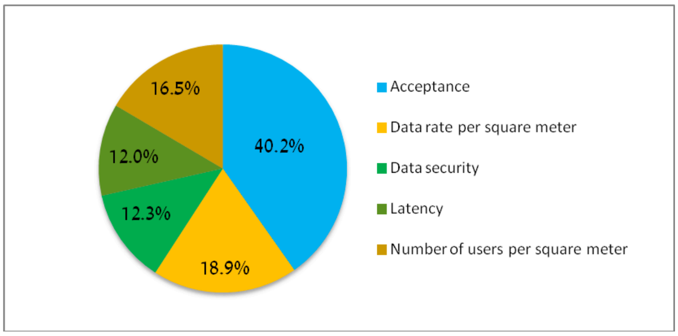

Fig. 2. Criteria weights for selection most promisng LiFi app averaged over all experts.

Acceptance weight received the highest score 40.2% in terms of importance followed by two criteria with similar importance of Drpsm 18.9% and Noupsm with a score of 16.5%. Similarly, DS and LAT with scores of 12.3% and 12%, respectively.

Examination of the criteria for each apps' weight as derived from AHP TransparentChoice S/W, is detailed in Fig. 3.

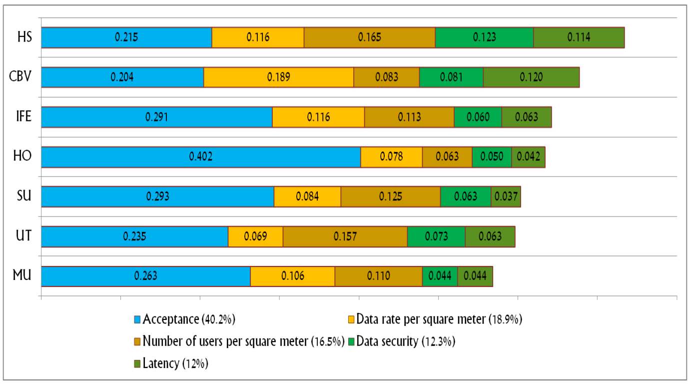

Fig. 3. Deatiled analysis criteria per each use case averaged over all experts.

Results of comparisons of each weight criterion versus each app is further detailed in the Table 1 below:

TABLE I: SCORES PER ALTENTATIVES

Score	Alternative - Full Name	Alternative - Short Name
0.734	Hospitals	HS
0.677	Communication Between Vehicles	CBV
0.643	In-flight entertainment	IFE

0.643	Home	HO
0.603	Supermarket	SU
0.597	Underground train	UT
0.568	Museum	MU

The results show that the difference between the usage of LiFi technology is approximately a moderate linear increase in apps' scores depending on the score. This indicates that the overall importance of all apps with the highest importance is HS and lowest is MU.

VI. SENSITIVITY ANALYSIS

A. Sensitivity Analysis of Acceptance Criterion

Within the sensitivity analysis, it can be seen to which extent variations in a criteria's weight affect the app's score. It can be seen that if the acceptance weight level is increased, then apps MU IFE, HO and SU, have significant increase in their apps' score (HO is the most sensitive app), where HS and CBV decreased. See Fig. 4 below.

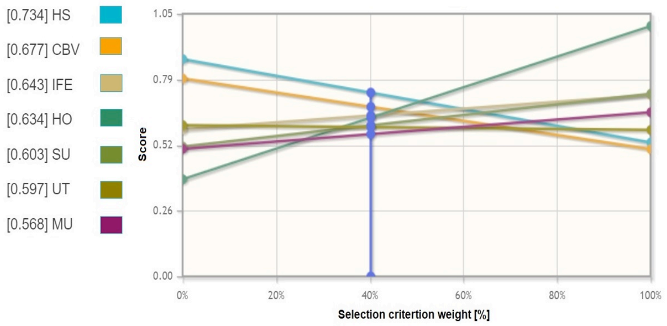

Fig. 4. Sensitivity analysis of all experts' Acceptance criterion versus criterion weight.

B. Sensitivity Analysis of Drpsm Criterion

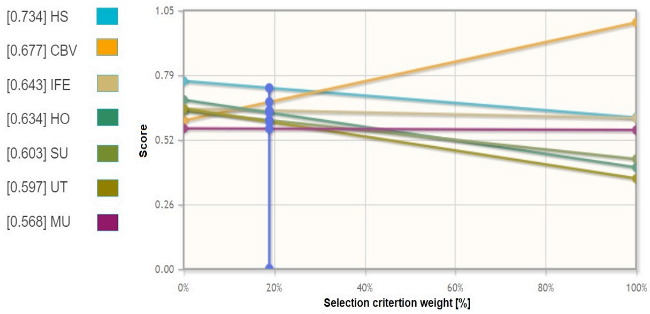

Fig. 5. Sensitivity analysis of all experts' Drpsm criterion versus criterion weight.

The sensitivity analysis shows that when increasing the Drpsm criterion weight then:

- CBV app (the most sensitive one) score has a significant increase change.
- IFE, MU apps will be virtually unchanged depending on the change in weight level criterion.
- For HS, HO, SU, UT apps, any additional weight increase in criterion level will lower the score.

C. Sensitivity analysis of DS criterion

The sensitivity analysis of the DS criterion weight against each app versus criteria weight is shown Fig. 6 below.

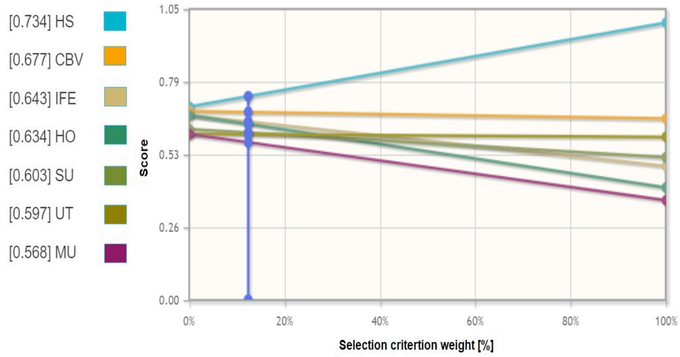

Fig. 6. Sensitivity analysis of all experts' DS criterion versus criterion weight.

The sensitivity analysis shows that when increasing the DS level in HS app (the most sensitive one), a significant increase in HS score will be noticed.
Apps CBV and UT will be virtually independent on criterion's weight change.
In App IFE, HO, SU, MU, each increment of the criterion's weight will lower the score.

D. Sensitivity analysis of Latency criterion

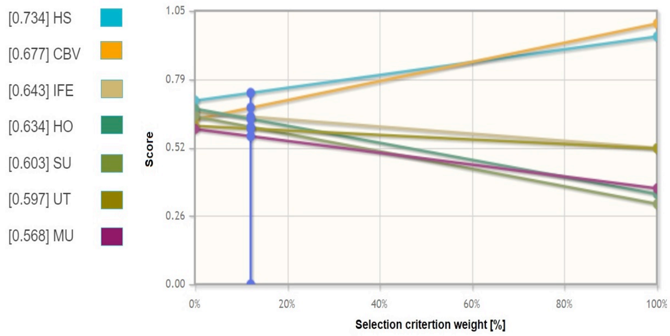

Fig. 7 Sensitivity analysis of all experts' latency criterion versus criterion weight.

The sensitivity analysis shows that if we increase the LAT criteria weight level then:
Apps HS, CBV (the most sensitive one) seem to have a significant change in its grade increase.
In apps IFE, HO, SU, MU, UT any additional weight criterion will lower the score.

E. *Sensitivity analysis of Noupsm criterion*

Sensitivity analysis of the weight of the Noupsm criterion:

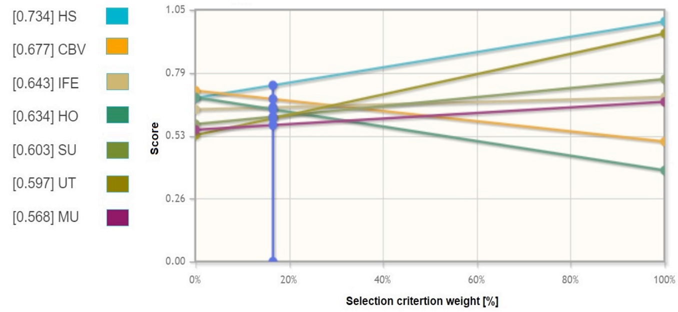

Fig. 8 Sensitivity analysis of all experts' Noupsm criterion versus criterion weight.

The sensitivity analysis shows that when increasing the weight level of Noupsm:

- Apps HS, SU, UT (the most sensitive one), MU had a significant increase in their score.
- App IFE and HO, will be virtually unchanged depending on the change in weight level criterion.
- Within CBV app, increasing weight's criterion will lower the score.

VII. SUMMARY

The AHP model reveals that the criterion "Acceptance" has the highest importance for the addressed apps. After it in the importance scale are Drpsm, Noupsm, DS and LAT has the lowest ranking. Detailed sensitivity analysis, which is an essential part of AHP model, was provided.

The impact of LiFi technology on each of the various apps is reflected in high data transfer rates. LiFi technology has transmission capabilities much greater than 1Gbps [18], with current transmission rates of ~300Mbps. In addition, LiFi technology is more secure for citations and does not cause electro-magnetic interference to EMC. The LiFi technology combined with 5G/B5G could serve as a key enabler for range of apps analysed through AHP model in this research, and many more apps to come in the near future.

Recommendations for further research

A larger data base of LiFi's experts should be incorporated in a more detailed AHP analysis consisting more apps. The 5G NR [7] is pointing at 74 use cases from which the larger set of most promising apps can be selected.

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