# Study of Decentralized RF and LiFi Networks as a Complement to Congestion in Centralized Networks

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**Abstract.** Congestion in current centralized networks is an increasing problem with the number of devices worldwide. Because of the above, enormous efforts have been made to provide new alternative solutions to this problem, such as decentralized networks. This work proposes a novel Peer-to-Peer (P2P) structure through Radio Frequency (RF) and Light-Fidelity (LiFi) technologies, performing a Discrete Event Simulation (DES) of the transmission times concerning the parameters and operation of each of these technologies. Besides, this research presents the impact of nodes and bandwidths variations for *Upload* and *Download* for this type of P2P network and their possible applications. Finally, the comparison between centralized networks and decentralized networks is analyzed.

**Keywords:** Peer-to-peer, Ligth-Fidelity, Radio-Frequency, descentralized, networking.

## 1 Introduction

According to Cisco, it is predicted that more than 500 billion devices will be connected to the Internet by the year 2030 [10]. All this is due to the rise of new technologies such as Internet of Things (IoT) and its increasingly daily use, which can range from process automation to the use of wearables that allow the monitoring of biomedical signals [9]; not to mention the multiple guides and technical manuals that exist for the implementation of this technology in almost any field [8].

Due to the reasons mentioned earlier, the communications between all these devices and sensors will have to be carried out mostly without human intervention, this may cause the rise of P2P active node structures and their variants (Machine-to-Machine (M2M), Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and others), which can better deal with the exorbitant amounts of data created and seem to complement centralized networks nicely.

For a long time, Radiofrequency networks have been studied by many researchers in the communications area; therefore, their areas of use and parameters are largely known. However, LiFi is a technology in the development process and constantly exploring its main niches, obtaining its areas of opportunity in hostile networks to radio frequency. Networks in which the nodes are static and those that require dedicated links without wiring. Thanks to its characteristics of high security in the physical and data link layer (OSI model), high bandwidth (unlicensed), high data density, and adaptability [6], LiFi is positioned as a technology that is perfectly compatible with P2P environments in the propagation of information of interest through all the nodes of the network.

## 2 Network Architecture

The architecture in data networks is related to structure, both, logical and physical organization of the components of a telecommunications network. Generally, architectures can be measured by standard parameters such as bandwidth, transmission speed, storage or processing capacity, the technologies used for their operation, the network topologies used, and how nodes interact on the net. Due to this last parameter, two architectures with a significant impact on current networks have traditionally been used: centralized architectures (Client-Server) and decentralized architectures (Peer-to-Peer) [7].

In recent years, the benefits of both technologies have been used to create hybrid architecture networks for applications such as adaptive video streaming [2], cloud applications, or multi-agent optimizations [3]. Figure 1 shows an example of the use of this environment.

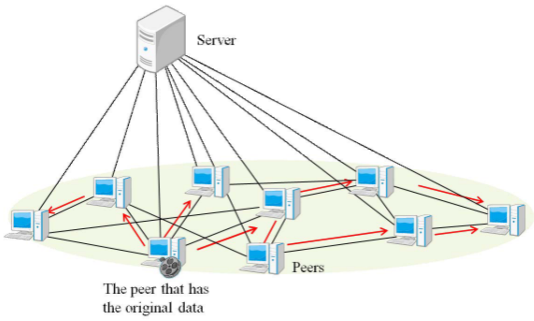



**Fig. 1.** P2P streaming environment.

### 2.1 Centralized Networks

Centralized architectures are characterized by having a main server from which other nodes obtain information. For these reasons, the main server often must present robustness of processing, storage, and bandwidth to supply the entire network. Otherwise, the phenomenon of congestion is shown, which in extreme cases can damage the entire network; thus, the server is vital for the centralized model.

On the other hand, centralized entities allow information control to be concentrated in a specific group of servers that can respond to transactions and are ideal for environments such as banking, government, universities, and others.

### 2.2 Descentralized (P2P) Network

Another computer architecture contains the Peer-to-Peer (P2P) model, which has become relevant in recent years. This architecture promotes the activity of all the nodes in the network since it segments the packets and allows each node to behave as a client and server, obtaining the segments (chunks) that it needs and sharing those it has.

Such as centralized networks, there is a client and a server. P2P networks have two types of nodes: Leechers and Seeds. Leechers are those nodes that do not have all the chunks, while Seeds are those nodes that have all the information available in the network (Leechers and Seeds [5] can share their information).

### 2.3 P2P Networks for RF and LiFi Technologies

In this work, the simulations of the technologies described in the preceding paragraphs are shown, proposing a centralized network that will have the same parameters as the decentralized networks and whose simulation will differ concerning the latter in obtaining information by the present nodes on the network by getting a server all over the network.

For the P2P-RF network, a maximum range network will be considered (all nodes in the network could potentially connect to each other). While for the P2P-LiFi network, its functionality is described in the simulation in section *3.1*. It is important to highlight that one of the essential points of this research is present in the visualization, approach, and simulation of P2P-LiFi networks, the implementation proposal for places with static or semi-static nodes, and a comparison with P2P-RF networks and centralized.

## 3 Results

This section details the results obtained in the simulations by discrete events of the system (DES) carried out for the technologies specified in subsection *2.3*. Also, the general considerations of the proposed scenarios are pointed out. Finally, the corresponding results to the dispersion of files across the network and the impact on the variation of the number of nodes in these environments were analyzed, and they are presented in the following sections of this work.

### 3.1 Node Description for Static and Semistatic Nodes

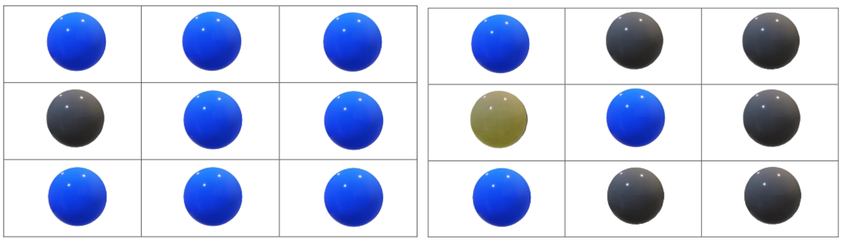
Since LiFi technology depends on unique characteristics for its communication, such as its field of vision and its line of sight, the ideal environments involve static or semi-static nodes, which is why these types of applications are excellent for places such as hospitals, museums, offices, industry, and classrooms.

For the proposed experiments, a centralized scenario is proposed through an RF network with a maximum coverage radius and two decentralized scenarios using the P2P architecture with LiFi and RF technologies, whose considerations are specified in Table 1.

**Table 1.** General considerations for P2P static and semistatic scenarios.

| Parameters | RF | LiFi |
|---|---|---|
| Max. Upload connections | 1 | 1 |
| Max. Download connections | 4 | 4 |
| Coverage radius | Max. | LOS |
| Noise and intereferences | not considered | not considered |
| Peer connection improvement (DES) | Yes | Yes |

The maximum data upload and download connections are used according to the classic model of some P2P networks.



**(a).** Maximum range P2P-RF network **(b).** LOS range P2P-LiFi network

**Fig. 2.** Description of a connection through proposed P2P-RF and P2P-LiFi networks.

Figure 2 describes that any node has a sufficient coverage radius to connect to another within the RF network. Meanwhile, in the case of the LiFi network, the nodes can only connect with those available in their Line Of Sight (LOS) and located at the four cardinal points.

Furthermore, Figure 2-a shows the maximum range P2P-RF network in which a node (black node) can connect to any other node within the network (blue nodes); then, maximum node reach allows all nodes within the network to be reached by the node that needs to connect. By another hand, Figure 2-b shows the LOS range P2P-LiFi network in which a node (red node) can connect to any other node within its LOS (blue nodes). It should be noted that some nodes are not reachable (black nodes) by the node that tries to obtain the information.

It is true that there are well-identified characteristics in this technology, such as high data density, bandwidths of up to 10Gbps (unlicensed), and transmission only under its Field Of View (FOV) aligned to the LOS of the same device, for which there is already a large number of works and prototypes that take into account all these characteristics in P2P environments [1,4]. However, LiFi devices are yet in the standardization process, study use cases, and constant development. Figure 3 is a clear example of the ways in which LiFi devices can be presented in different areas. This LiFi device could be a prototype for the physical realization of the P2P-LiFi network proposed in this work.

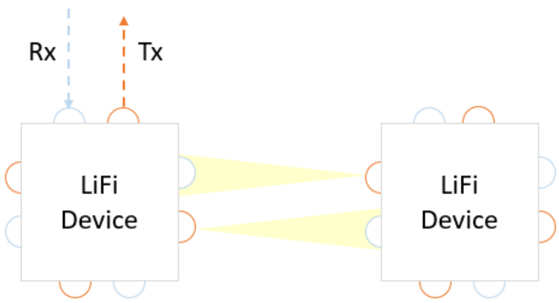



**Fig. 3.** DES implemented for the case of 8 nodes in the centralized, P2P-RF, and P2P-LiFi technologies.

### 3.2 DES for Centralized and Descentralized Environments

DES processes allow systems to be recreated through their characteristics and behaviors over time. At a first glance, the simulation for this work recreated the behavior of P2P networks regarding connection, disconnection, election, births and deaths of nodes and adapted these aspects to the proposed scenarios.

P2P systems have been studied daily from Markovian models using queuing systems to describe the number of average Seeds and Leechers and the service times in the system. The previous is directly linked to the dynamics of classic P2P systems according to the constant movements, connections, and disconnections through the nodes present in the network. However, the main objective of the case study of this article is not the dynamics of the movement of the nodes over time; since it is intended for communication networks in which the nodes are static or semi-static.

Therefore, the number of Leechers and Seeds through time remains constant due to the nature of the proposed technologies. Consequently, the object of study in this type of system is the file's download time through all the nodes present in the network, which is calculated through Discrete Events Simulation (DES) as described in Algorithm 1.

```
Data: nodes, μ, radius
Result: timesimulation
timesimulation ← 0;
seeds ← 1;
leechers ← 1;
Add(seed);
seeds ← seeds + 1;
i ← 0;
while i < nodes − 1 do
    Add(leecher);
end
while seeds < nodes do
    conversions ← leechers2seeds(timesimulation);
    seeds ← seeds + conversions;
    event ← event.getfront();
    timesimulation ← event.time();
end
```

**Algorithm 1:** Discrete Event Simulation (DES) algorithm performed for P2P-RF and P2P-LiFi networks.

The performed DESs obtain the total time in which a file is shared through the network of nodes, taking into account the nature and characteristics of each technology to connect and transfer information. The previous algorithm also shows that each time an event is fulfilled, Leechers that for that time $t$ could be converted into Seeds are updated. Finalizing the simulation when all the nodes have been converted into Seeds.

### 3.3 Information Sharing over Time and the Impact of Network Node Variation

This part of the work shows the relevant results of this research. These results are shown through surfaces that reflect the behavior of the information transmission times along the different bandwidths shown in Table 2. Following what was stated in the previous lines, *Figure 4* shows in the first instance that although the variation of the data download bandwidth ($c$) also impacts the total transmission time.

The upload bandwidth of the data ($\mu$) represents a bottleneck for the system, which also causes an impact on the sharing times of the system for the given criteria. One thing to confirm in the graphs is that the higher the bandwidth, the shorter the time it takes for the information to propagate through the nodes.

**Table 2.** Number of nodes and bandwidths utilized in DES.

| **Parameter** | **Values** |
|---|---|
| $\mu$ | [0.001, 0.002,0.003,0.004,0.005] |
| $c$ | [0.01, 0.02,0.03,0.04,0.05] |
| Nodes | [4,8,12,16,20,24,28,32,36] |

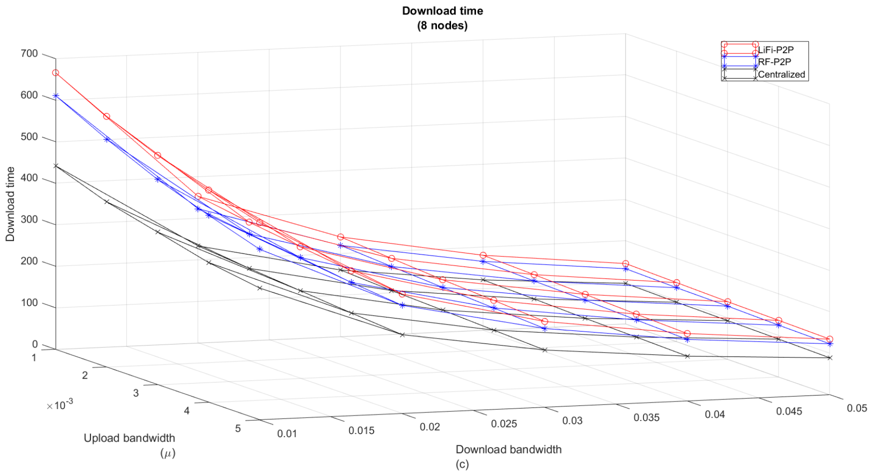
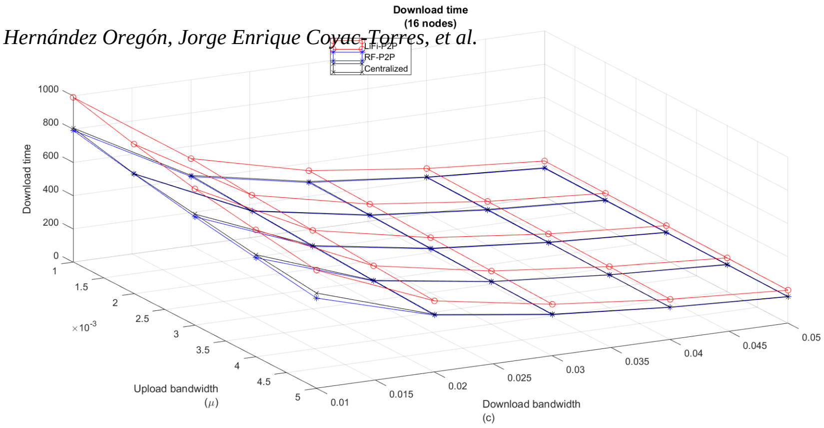


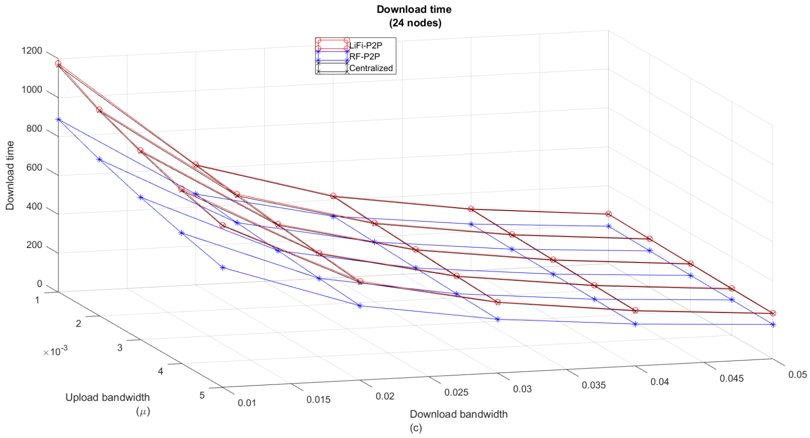

**Fig. 4.** Performed DES for the case of 8 nodes in centralized, P2P-RF, and P2P-LiFi technologies.

In addition to the variation of the bandwidths $\mu$ and $c$, in *Figure 5* we can look at the behavior of these networks from another perspective due to the number of nodes that the network takes into account. Simulation of the proposed system. The centralized technology obtains better performance for the case of few nodes, while, as the number of nodes increases, the P2P networks begin to work better; this is because the centralized network becomes congested, and the decentralized networks begin to spread the information through Leechers constantly turning into Seeds in the system.

For the case of the P2P-RF network, it can be seen that a connection with the centralized network is achieved at 16 nodes (*Figure 5-a*). Meanwhile, the breaking point for the P2P-LiFi network is located at 24 nodes (*Figure 5-b*).




**(a).** Performed DES for the case of 16 nodes in centralized, P2P-RF, and P2P-LiFi technologies.

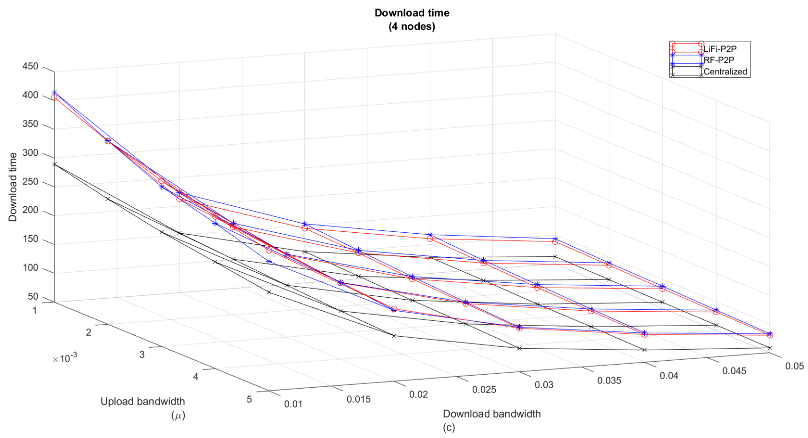



**(b).** Performed DES for the case of 24 nodes in centralized, P2P-RF, and P2P-LiFi technologies.

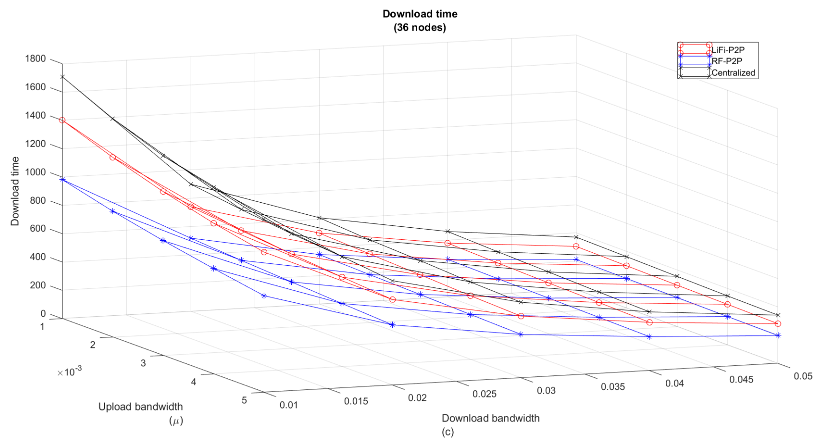
**Fig. 5.** Breakpoints of P2P networks concerning centralized network.

As discussed in previous paragraphs, P2P networks are rarely affected by a plethora of nodes. On the contrary, they generally show better performance in environments with a large number of nodes. The *Figure 6* confirms the previous assertion, observing that for 36 nodes (*Figure 6-b*), the behavior of the P2P-RF and P2P-LiFi networks show shorter information sharing times than in the centralized network.

It should be noted that the P2P-RF network always presents lower transmission times than the P2P-LiFi network due to the maximum range coverage it presents and the intrinsic nature of LiFi technology to transmit in its line of sight.




**(a).** Performed DES for the case of 4 nodes in centralized, P2P-RF and P2P-LiFi technologies.




**(b).** Performed DES for the case of 36 nodes in centralized, P2P-RF and P2P-LiFi technologies.

**Fig. 6.** Impact of node variation in P2P and centralized networks.

# 4 Conclusions

This work proposes a new approach to decentralized networks through the concept of P2P networks applied to static and semi-static networks. It also exposes the study of the impact of parameters such as number of nodes and bandwidths in the proposed environments and compares their performance with that of a centralized network. The article describes the discrete event simulation of the proposed systems and the proposed comparisons, and reports the results obtained.

P2P-RF and P2P-LiFi networks presented a better performance with a more significant number of nodes than the centralized network, showing that this kind of network can be an excellent complement to congestion as we could see into performance comparation between P2P and centralized networks(essential part from this paper). On the other hand, it may be affirmed that due to the different operation of each technology there was a variation in the times for data sharing, in which, LiFi always was maintained with greater times than RF, for above, future work will address standardized bandwidths for each technology in order to have a new differentiator between these proposed P2P networks and thus be able to see the opportunity areas for LiFi over RF.

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