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Efficient Video Distribution in P2P Networks

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Context

Nowadays, video services represent more than half the traffic in telecommunication networks worldwide (57.69%) [1].

From these services, Video on Demand (VoD) are the most dominant: Just the three more popular services comprise 30% of world wide traffic.

This demand is expected to grow by 2024, where more than 70% of this traffic will go through a mobile device [2].

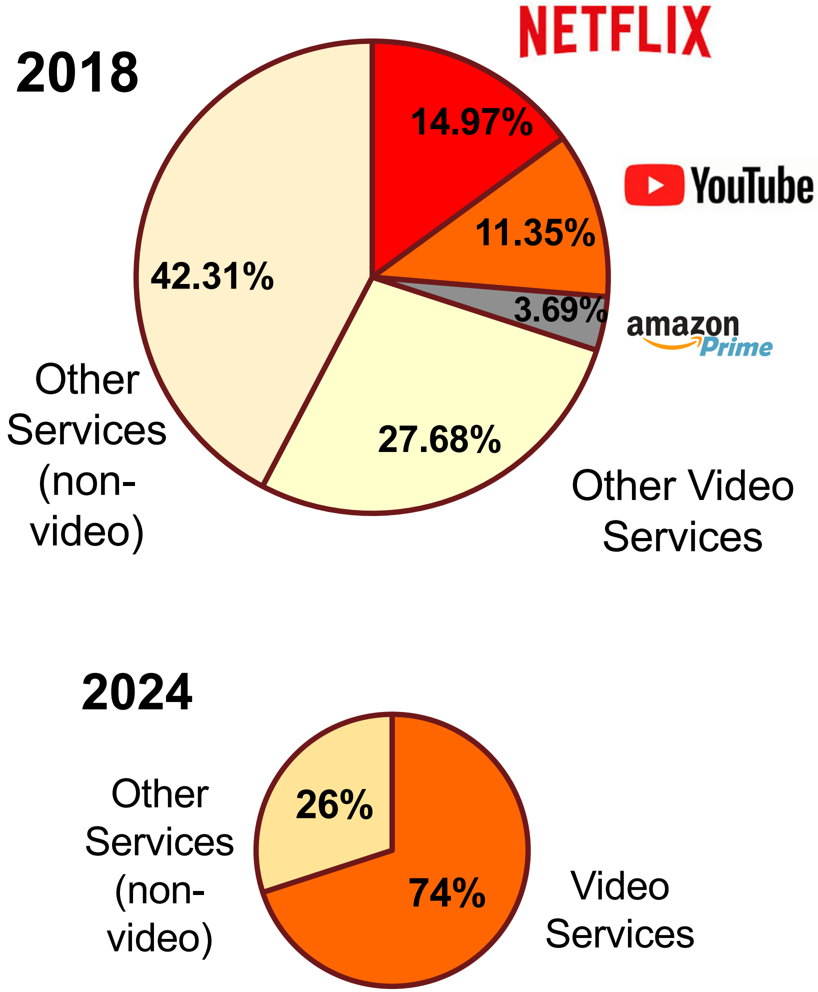

Fig. 1. *Current Internet Traffic* (2018) *and eexpected traffic by 2024.*

According to multiple studies, from the catalog of a VoD service, only a few files are extremely popular [3]: Many users are interested on downloading the video file.

This high demand can be met in an efficient manner using P2P networks: All users act as servers and clients, sharing their parts of the files with other peers.

In these networks, a high demand also increases resources in the system, then, it is scalable [4].

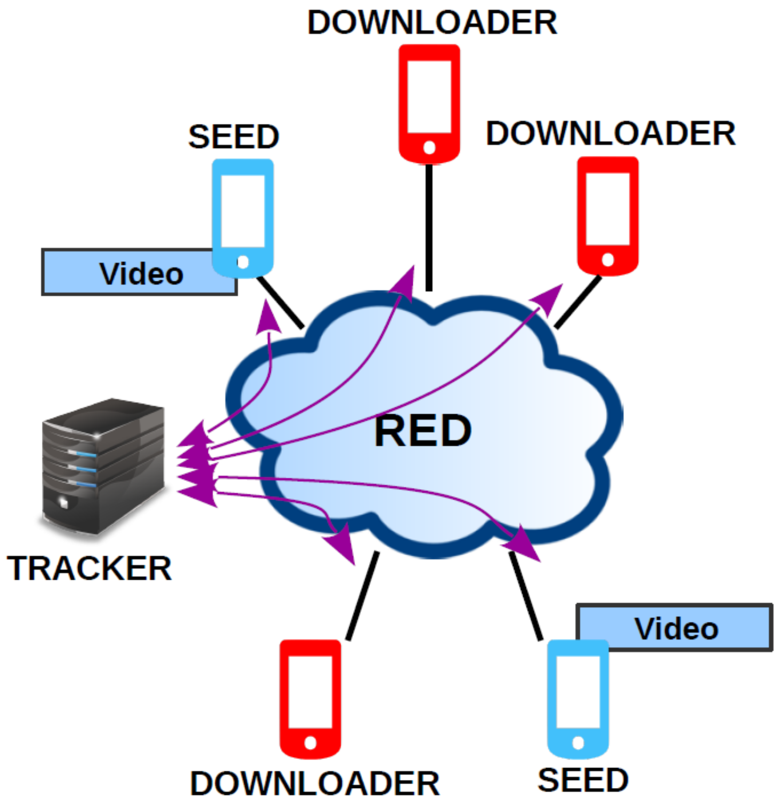

Fig. 2. *General structure of a P2P network.*

P2P networks are considered as an essential part of services in the **5G** communication networks

New technologies in the 5G systems are expected to be cooperative, using resources of mobile devices to reduce costs and energy requirements (**Green Communications**).

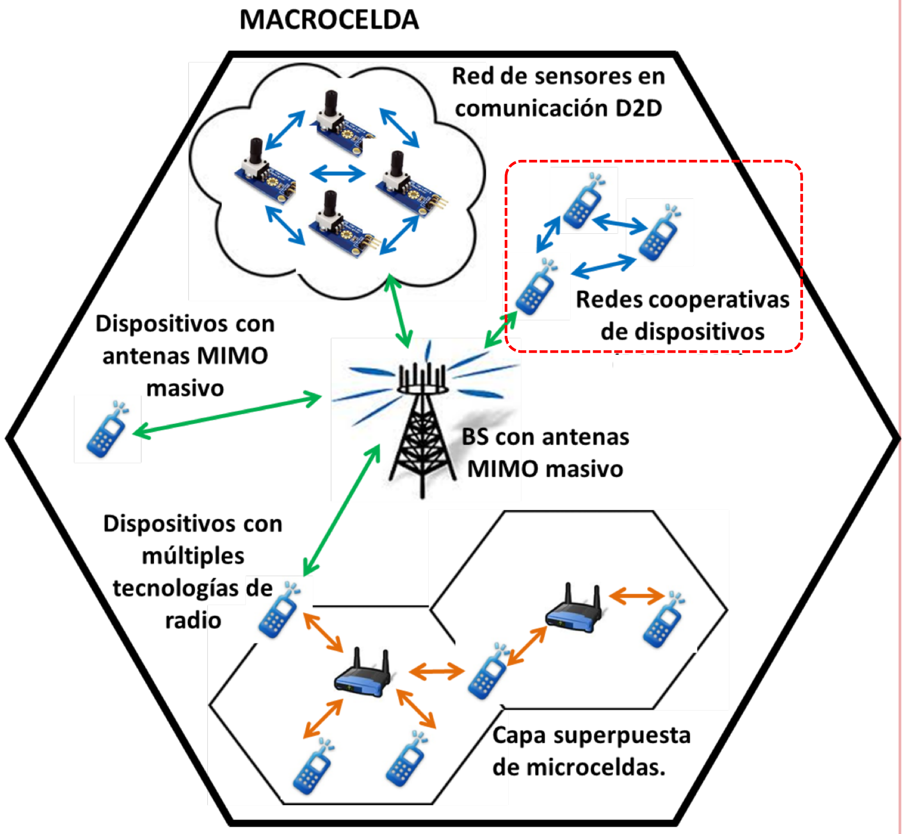

Fig. 3. *Technologies considered in an heterogeneous 5G network.*

Basic Model

A **fluid model** is developed considering:

A set of peers are interested on downloading a video file that **can be reproduced before complete download**.

The video file is composed by ***chunks*** of the fie. A set of neighbors chunks form a ***window***.

There is a ***tracker*** server that keeps the record of the chunks uploaded/downloaded by each peer in the system.

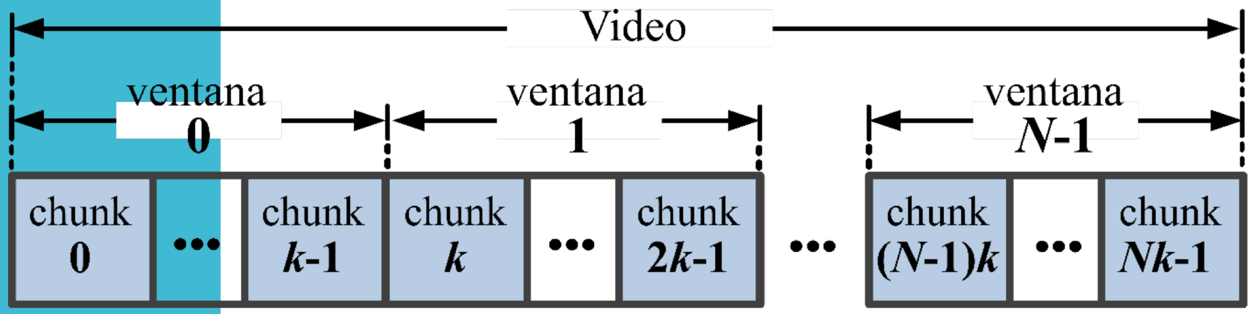

Fig. 4. *Division of chunks and windows of a video file.*

Peers with no chunks or with a partially downloaded file are called ***leachers*** (downloaders).

Peers with all the file are called ***seeds***.

New peers arrive to the system with rate λ and begin the download at window 0.

Seeds leave the system at rate γ.

Leechers leave the system at rate θ.

Leechers that complete the download of the file become seeds.

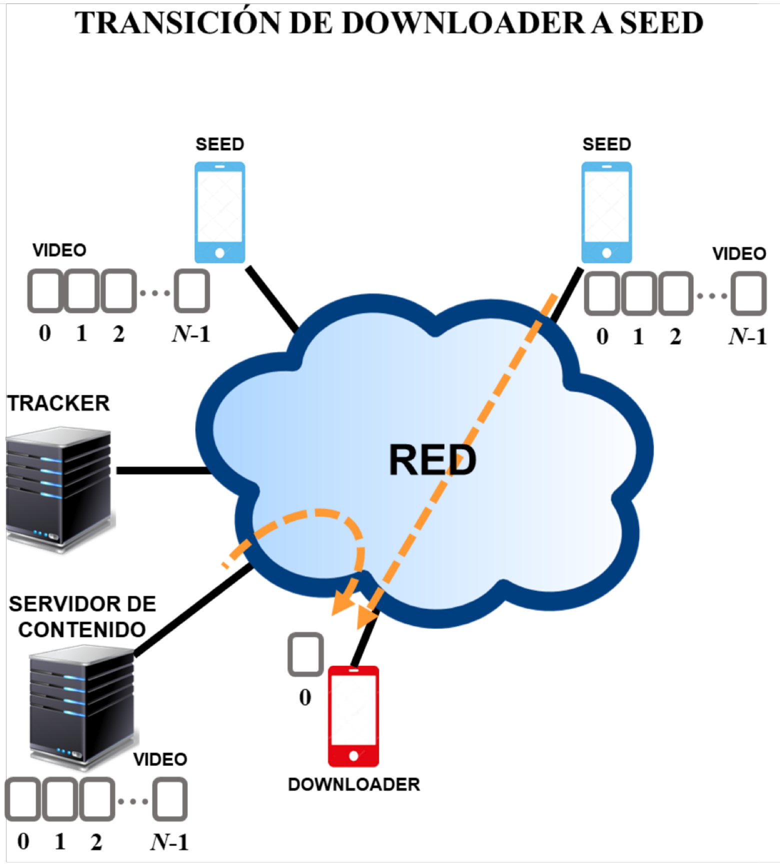

Fig. 5. *System evolution of a window-based P2P for video services.*

Clasificación Unidimensional (continuación)

To consider **QoE** parameters: Initial video reproduction delay; Pause probability; Pause delay.

The **first window** can be considered with a different size from the rest of windows.

Additional servers with all the file can assist the P2P network.

File distribution can be different (bandwidth) at each window.

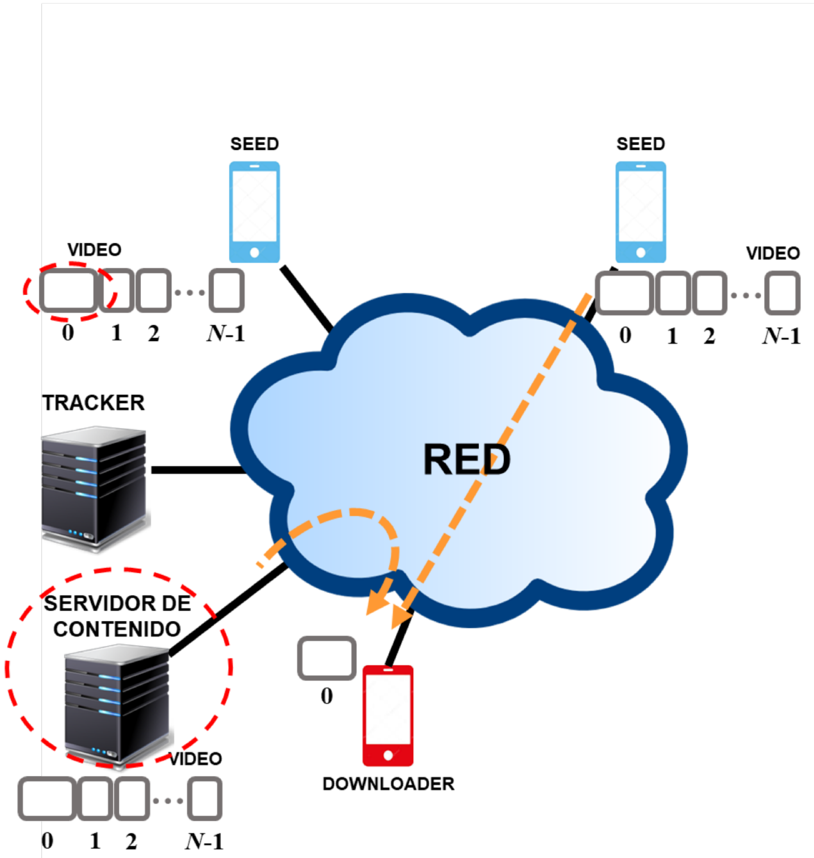

Fig. 6. *Additional considerations to provide QoE.*

Peers are classified according to the window that they are downloading.

The Fluid model defines the number of leechers at window *j*, $x_j(t)$, and the number of seeds, $y(t)$.

τ_j is the rate at which each peer progresses in the download process from window *j* to window *j*+1.

If the available bandwidth at window *j* (τ^p_j) is higher than the required bandwidth (τ^a_j), then the system is in **abundance** in window *j* ($\tau_j=\tau^a_j$). If not, the system is in **penury** in that window ($\tau_j=\tau^a_j$).

$$x'_0(t) = \lambda - \theta x_0(t) - \tau_0\,,$$

$$x'_j(t) = \tau_{j-1} - \theta x_j(t) - \tau_j\,,$$

$$y'(t) = \tau_{N-1} - \gamma y(t),$$

$$\tau^a_j = c_w x_j(t)$$

$$\tau^p_j = \mu_w x_j(t)\left(\sum_{J=j+1}^{N-1} \frac{x_J(t)}{\sum_{m=0}^{J-1} x_m(t)} + \frac{y(t)}{x(t)}\right)$$

Nomencalture.

c_w: Download rate of each peer in a given window.
μ_w: Upload rate of each peer in a given window.

Then there is abundance at window *j*, if $\tau^a_j \leq \tau^p_j$ and **abundance in the whole system**, if this condition is met **for all** values of ***j***.

Solving the differential equations in **stable state** and in **abundance** (to provide QoE), we obtain expressions for the number of peers in the system.

In case of penury, the number of seeds goes to 0, and peers at window j+1 also goes to 0.

$$X_j = \frac{\lambda c_w^j}{(\theta + c_w)^{j+1}}$$

$$Y = \frac{\lambda}{\gamma}\left(\frac{c_w}{\theta + c_w}\right)^N$$

$$X = \sum_{j=0}^{N-1} X_j$$

$$= \frac{\lambda}{\theta}\left[1 - \left(\frac{c_w}{\theta + c_w}\right)^N\right]$$

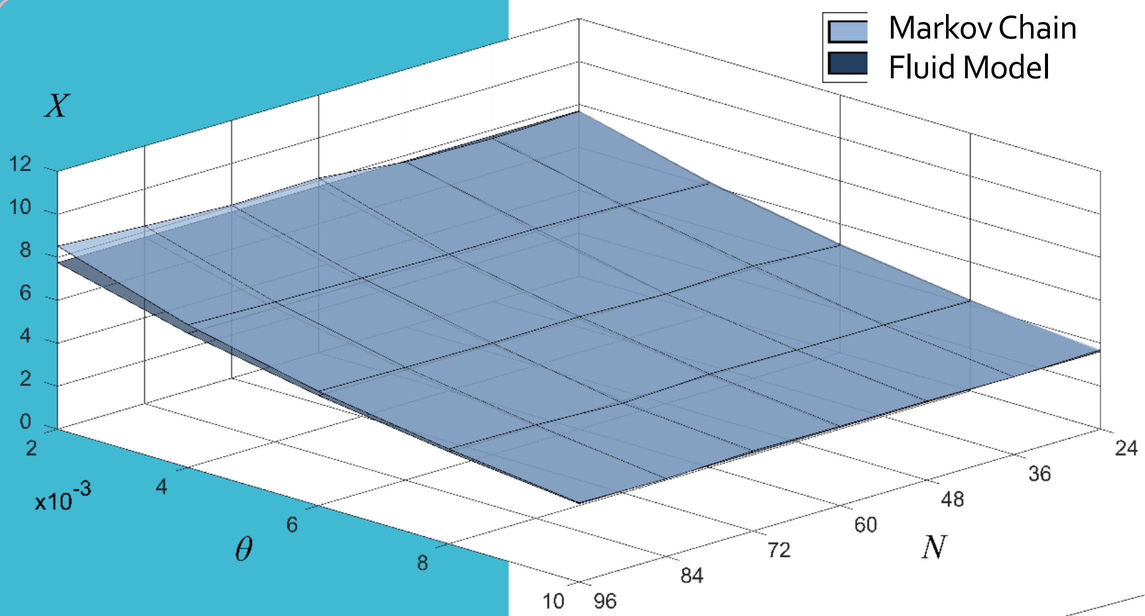

Fig. 7. *Number of Leechers at each window in steady state.*

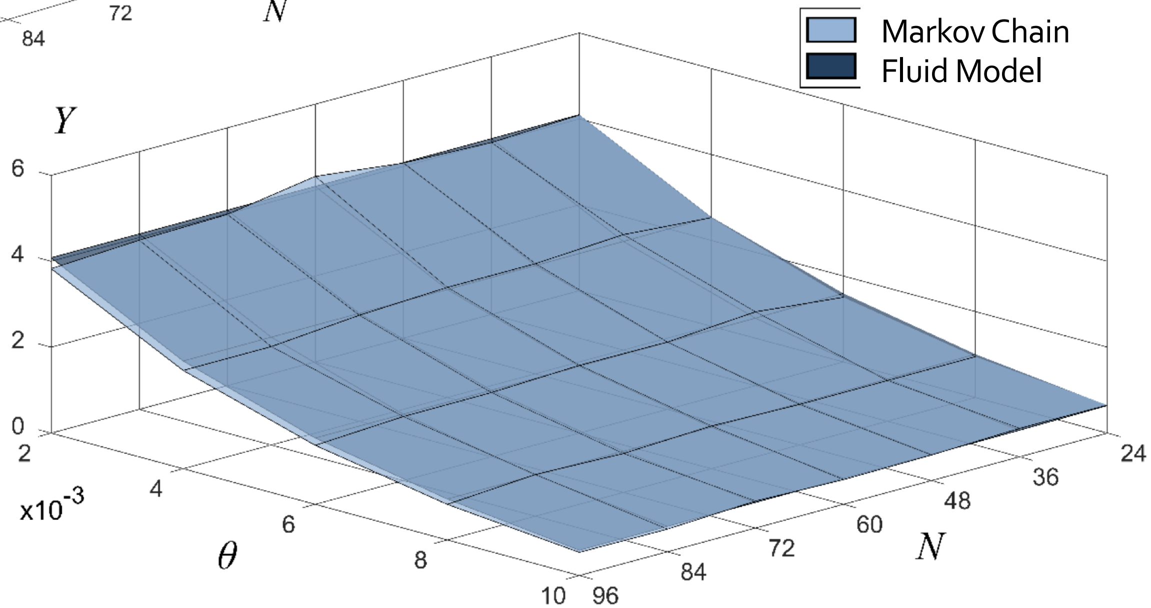

Fig. 8. *Number of seeds in steady state.*

System Design

Considering the abundance conditions $\tau^a{}_j \leq \tau^p{}_j$ for all values of j, we can determine system operation parameters to guarantee abundance in the system (considering uniform distribution among windows):

- Maximum departure rate of seeds to guarantee abundance (γ_{max}).
- Bandwidth provided by external servers to guarantee abundance (ν_{min}).

$$\gamma_{max} = \frac{\theta \mu_w c_w^{N-1}}{(\theta + c_w)^N - c_w^N}$$

$$\nu_{min} = \lambda \left[\frac{c_1}{\theta} \left(1 - \frac{c_1^N}{(\theta + c_1)^N} \right) - \frac{\mu_1}{\gamma} \frac{c_1^N}{(\theta + c_1)^N} \right]$$

Nomenclature.

c_1: Download rate of a peer at any non-cero window.
μ_1: Upload rate of a peer at any non-cero window.

Priority Distribution (DVP)

Uniform bandwidth distribution among windows entails a low bandwidth (AB_j) in upper windows (few peers can contribute chunks to these windows).

This entails also that seeds and external servers have to provide high bandwidth to maintain abundance.

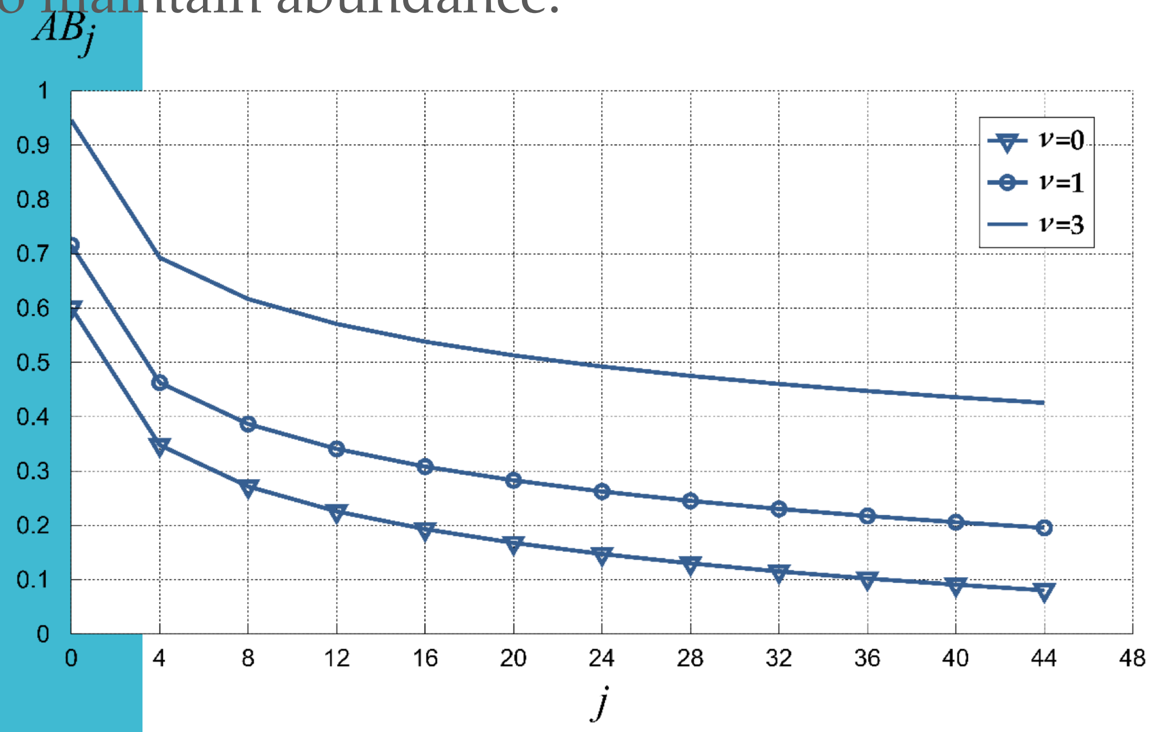

Fig. 10. *Available bandwidth per peer in each window.*

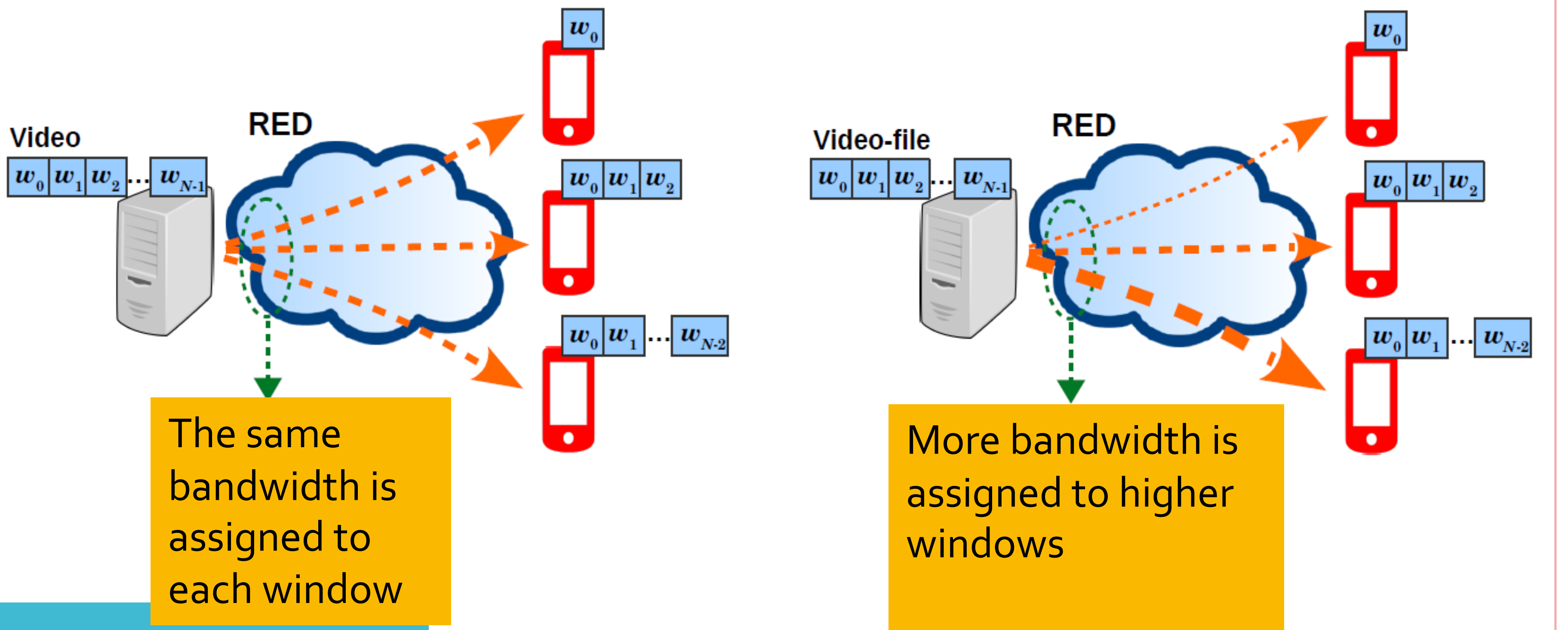

Fig. 11. *Comparison between UD and DVP.*

$$\tau_j^p = X_j \mu_1 \left(\sum_{J=j+1}^{N-1} \frac{X_J}{V_{J-1}} + \frac{Y}{X} \right) + \frac{\nu X_j (j+1)^\varepsilon}{\sum_{m=0}^{N-1} X_m (m+1)^\varepsilon}.$$

Now, change rate, $\tau^p{}_j$, is re-defined according to control parameter, **ε.**

In DVP, as ε **increases the more priority assigned to higher windows**.

When **ε=0** there are no priorities, and **DVP** becomes **UD**.

We find the appropriate value of ε such that it **minimizes** the required bandwidth from external servers.

Nomenclature.

***V_J*:** Number of peers downloading from windows 0 to *J*.

***ν*:** Bandwidth provided by external servers.

ε: Control parameter.

… DVP

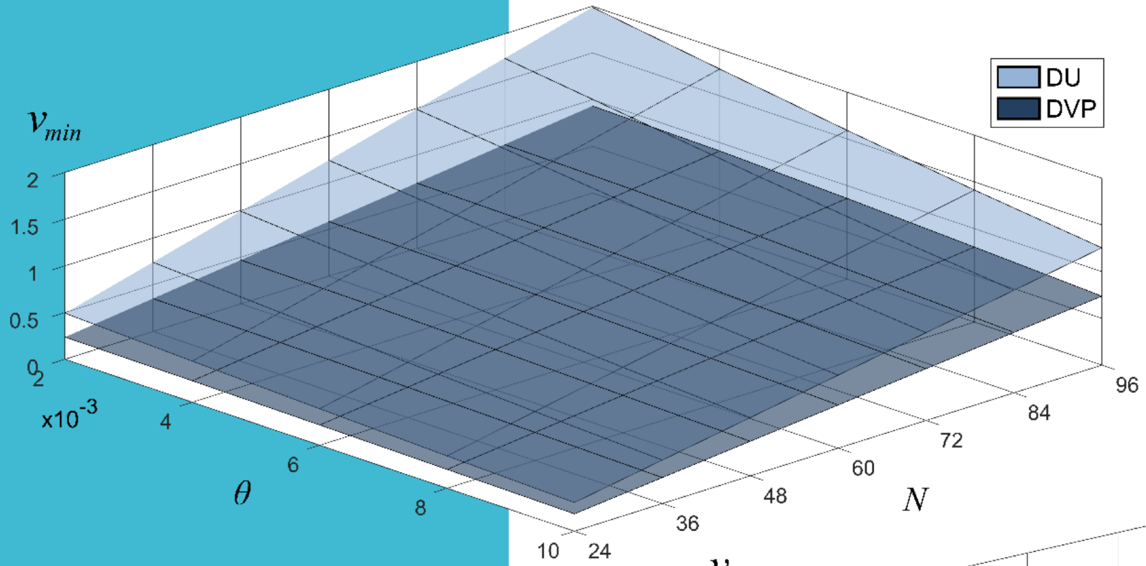

Fig. 12. *Bandwidth of external servers for each scheme.*

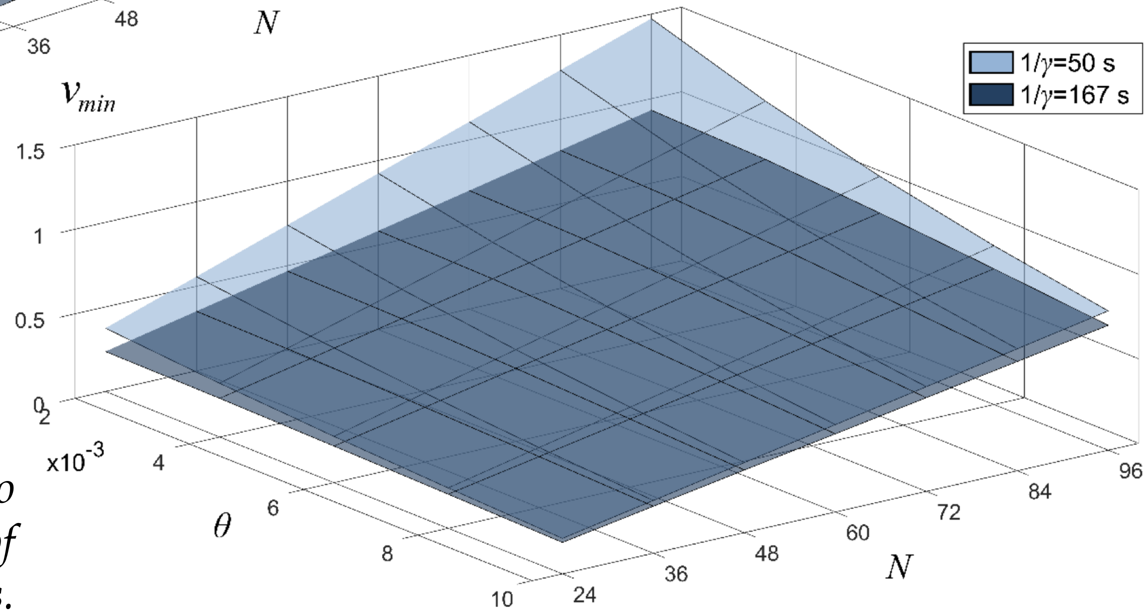

Fig. 13. *Bandwidth required to provide abundance in function of the cooperativity of seeds.*

QoE Guarantees

The main QoE parameters considered are:

- Initial video reproduction (**RI**).
- Average complete file download.
- Probability distribution of forced pausing (**PF**).

$$f_{t_0}(x) = (c_0 + \theta)e^{-(c_0+\theta)x} 1(x \geq 0)$$

$$T_0 = \frac{1}{c_0 + \theta}$$

$$T = \frac{N}{c + \theta}$$

$$f_{f_0}(x) = \left[1 - e^{-(c_1+\theta)\delta_0}\right]\delta(x) + \cdot (c_1 + \theta)\, e^{-(c_1+\theta)(x+\delta_0)} 1(x \geq 0)$$

Nomenclature.

c_0: Download rate of the initial window.
c_1: Download rate of non-initial window.
δ_0: Reproduction time of the initial window.

Multidimensional Classification

In order to have a more detailed description of the system, we classify peers according to the download window (**j**) and the reproduction window (**k**). This allows:

- Directly observe the number of leechers in the initial window and/or lecchers in forced pause.
- Model download restrictions typically imposed by mobile devices.
- Model interaction functions like intentional pausing, forward, reward in the reproduction.

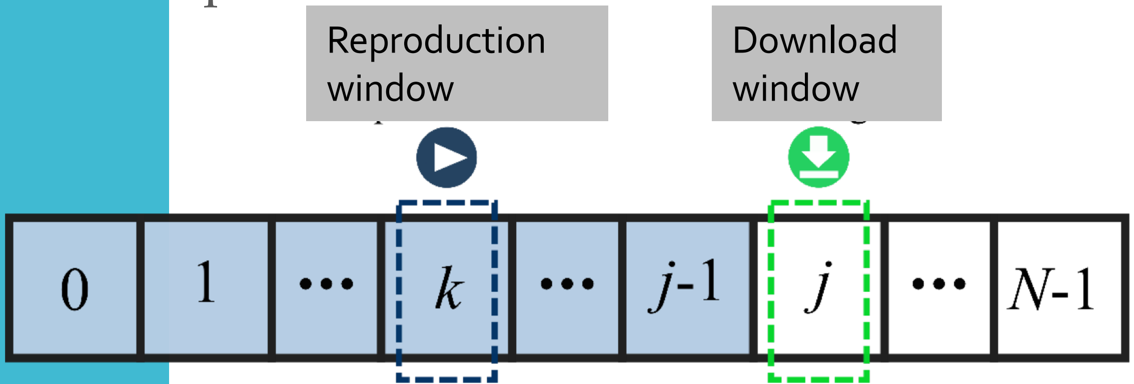

Fig. 16. *Download and reproduction for a peer classified in group (j, k).*

We now denote the number of peer in group **(*j*,*k*)** as $x_{j,k}(t)$ at time *t*.

We now identify them in a plane where interactions between groups are visible:

- Regular leechers
- Leechers in forced pausing
- Regular seeds
- Cooperative seeds

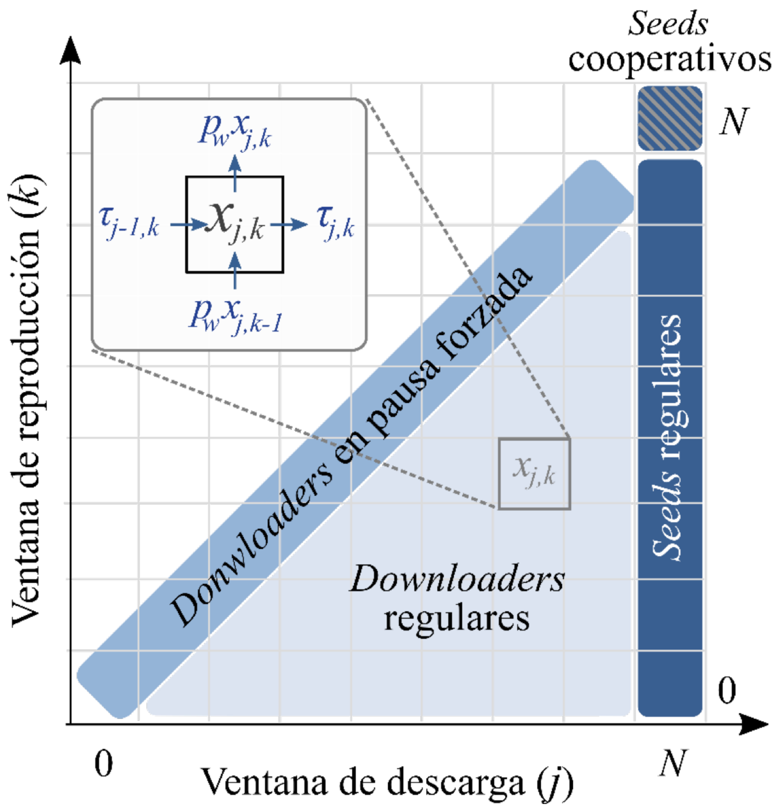

Fig. 17. *Classification of peers in the bidimensional model.*

In steady state, we obtain the following equations:

$$\lambda - r_w X_{0,0} = 0$$

$$c_w X_{j-1,0} - t_w X_{j,0} = 0; 0 < j < N$$

$$c_w X_{j-1,k} + p_w X_{j,k-1} - t_w X_{j,k} = 0; 0 < j < N, 0 < k < j$$

$$p_w X_{j,j-1} - r_w X_{j,j} = 0; 0 < j < N$$

$$c_w X_{N-1,0} - s_w X_{N,0} = 0$$

$$c_w X_{N-1,k} + p_w X_{N,k-1} - s_w X_{N,k} = 0; 0 < k < N$$

$$p_w X_{N,N-1} - \gamma X_{N,N} = 0$$

Donde $r_w = (\theta + c_w)$, $s_w = (\theta + p_w)$ and $t_w = (\theta + c_w + p_w)$.

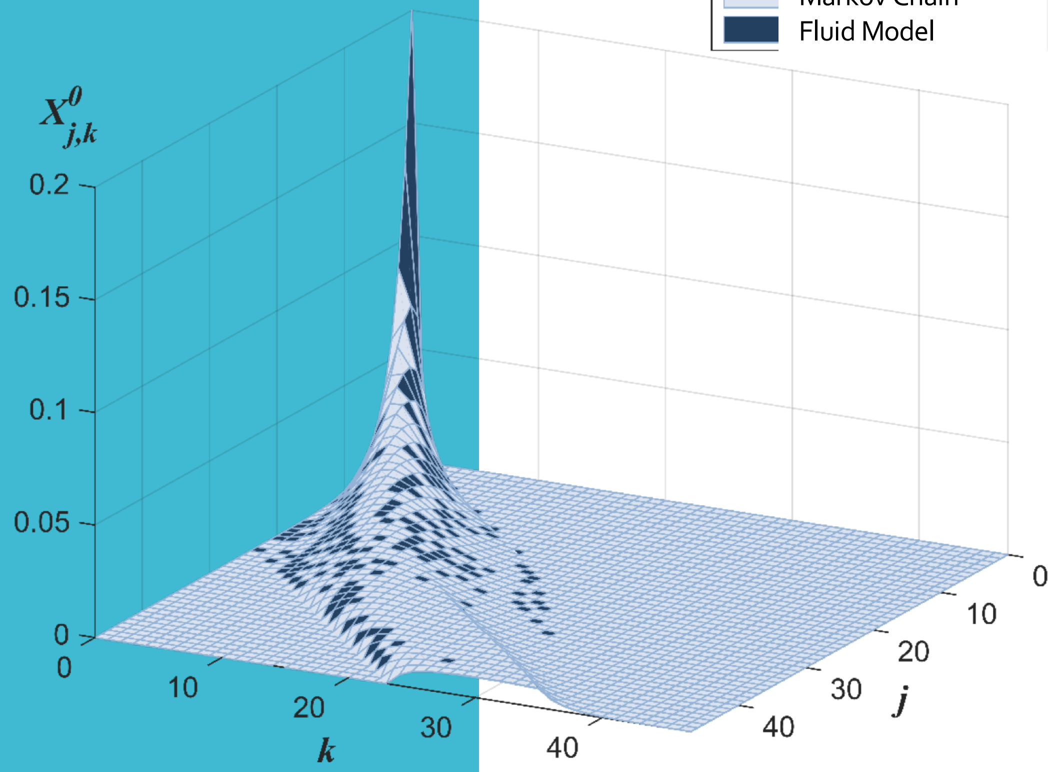

Fig. 18. *Number of peers reproducing the file in abundance conditions.*

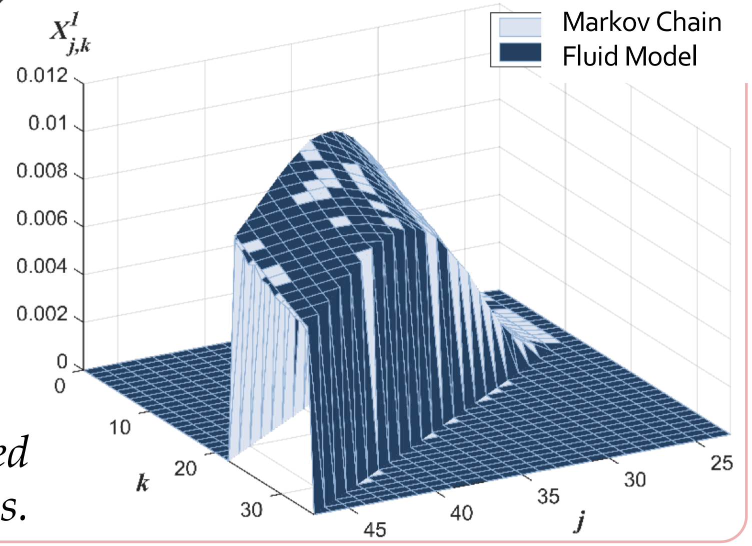

Fig. 19. *Number of peers in forced pausing in abundance conditions.*

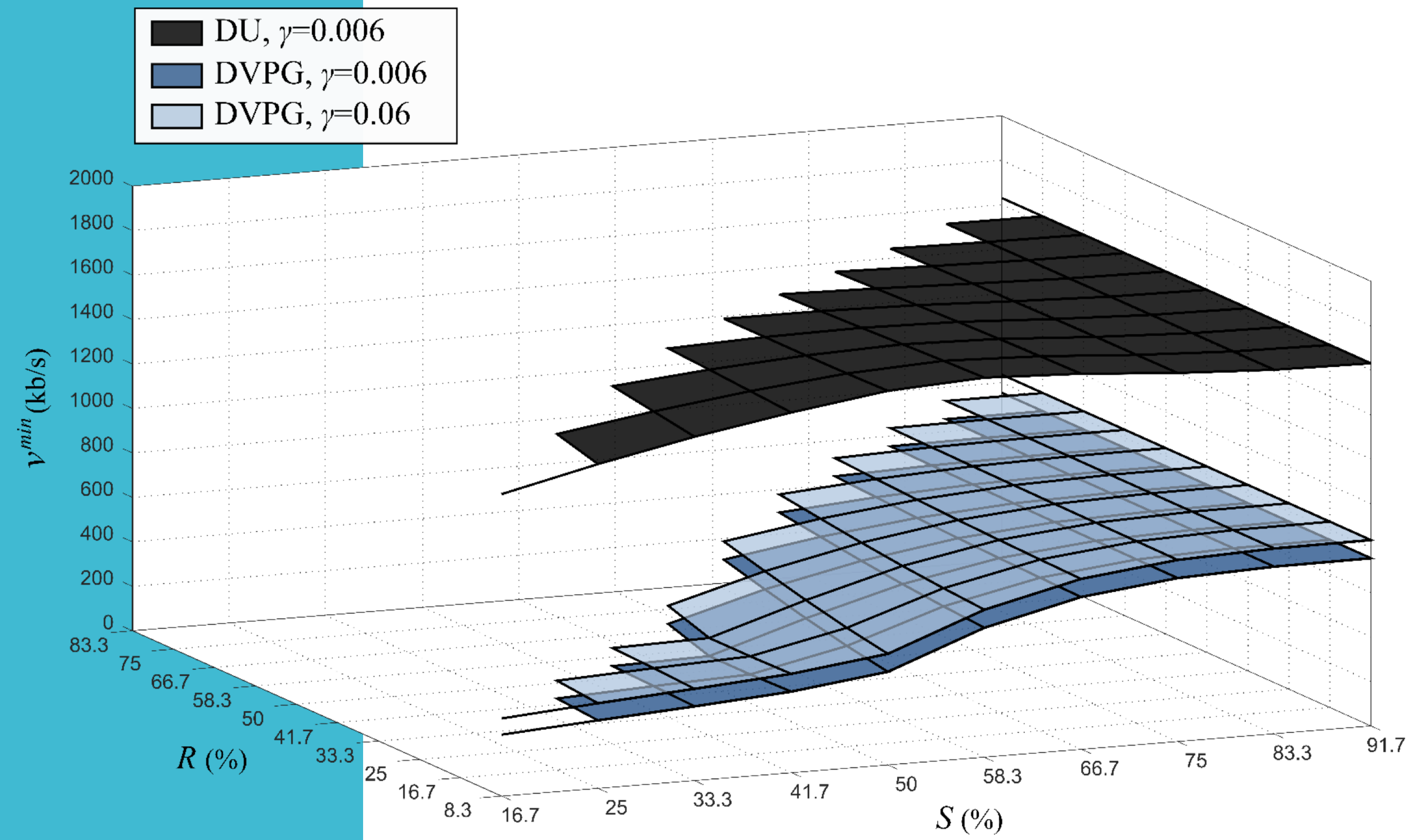

Fig. 20. *Bandwidth required by external servers to provide abundance.*

Conclusions

P2P networks can provide a video service efficiently, at low cost and low bandwidth requirements.

The system has to be carefully designed in order to reduce external bandwidth.

The P2P system can guarantee QoE for streaming video on demand.

To efficiently distribute the video:

-Select carefully the initial window

-Distribute resources according to the downloading window

-Use a multidimensional model to visualize download and reproducing windows.

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Merci !

- Questions ?
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