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Designing a Private CDN with an Off-Sourced Network Infrastructure: Model and Case Study

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CDN overview

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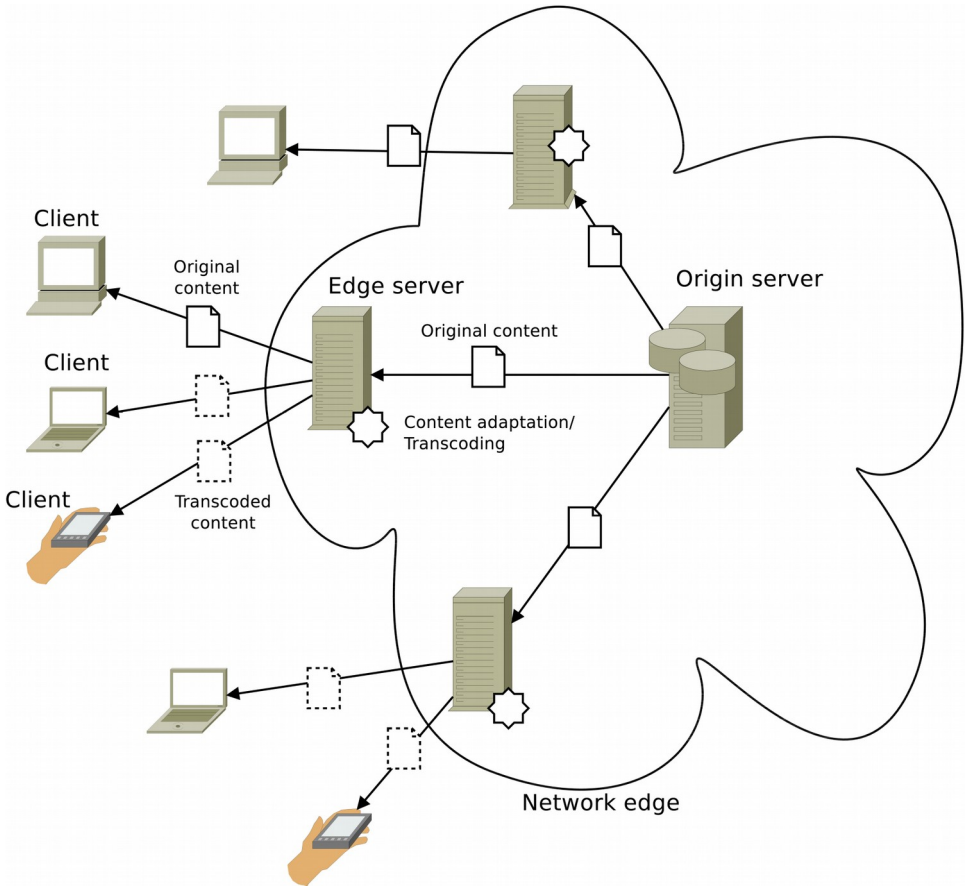
- Content Delivery Network
- Origin server
- Edge servers
  - De-multiplexing
  - Transcoding
  - Located on network edge
- Heterogeneous clients



Introducing P-CDN

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- Content provider is also:
  - Content consumer
  - CDN manager
- Network infrastructure outsourced
- Differences with traditional CDN
  - Different workload
  - Limited control over network infrastructure
- → Available literature not suitable for this scenario

Model overview (simplified)

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- Minimize number of edge server (1.1)
- Do not exceed download bandwidth (1.2)
- Do not exceed origin server bandwidth (1.3)

1 *if edge*
0 *otherwise*

$$\min \sum_{l \in \mathbf{L}} E_l \tag{1.1}$$

subject to:

BW if not edge *BW if edge*

$$BWd_l \geq \overline{E_l} \sum_{t \in \mathbf{T}} BW_t \cdot |\mathbf{C}_{t,l}| + E_l \cdot \max BW_t \quad \forall l \in \mathbf{L}, \tag{1.2}$$

BW of location l

$$BWo \geq \sum_{l \in \mathbf{L}} \overline{E_l} \sum_{t \in \mathbf{T}} BW_t \cdot |\mathbf{C}_{t,l}| + \sum_{l \in \mathbf{L}} E_l \cdot \max BW_t \tag{1.3}$$

Heuristics

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- Allocate bandwidth to clients
- Possible outcome
  - No clients supported
  - Some clients not supported
  - Partial client support
  - Complete client support
- Place edge servers (Thr)
- Manage satellite locations

Algorithm 1 Client bandwidth allocation

Require: $\mathbf{C}_l$
Ensure: $t_c \quad \forall c \in \mathbf{C}_l$
  for $t \in \mathtt{sort}(\mathbf{T} \cup \{na\} \uparrow)$ **do**
    for $c \in \mathbf{C}_l$ **do**
      $BWd_l \leftarrow BWd_l + BW_{t_c} - BW_t$
      if $BWd_l \geq 0$ **then**
        $t_c \leftarrow t$
      else
        break
      end if
    end for
  end for

Heuristics

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- Find closest locations to each edge
- Try to add as satellite locations (if BW is OK)
- Re-iterate
- Note:
  - NO Satellite locations too far form edge
  - Should be an optimization

Algorithm 2 Management of Satellite locations

Require: $\mathbf{L}$, $\mathbf{L_e}$, $niter$, $minBW$
Ensure: $\mathbf{L_{se}}, \forall e \in \mathbf{L_e}$
  $\mathbf{L_s} \leftarrow \mathbf{L} - \mathbf{L_e}$
  $\mathbf{L_{se}} \leftarrow \emptyset, \forall e \in \mathbf{L_e}$
  for $i \in [1, niter]$ **do**
    for $s \in \mathbf{L_s}$ **do**
      $e \leftarrow$ `nearestEdge`$(s, \mathbf{L_e})$
      Add s to $\mathbf{L'_{se}}$
    end for
    for $e \in \mathbf{L_e}$ **do**
      for $s \in$ `sort`$(\mathbf{L'_{se}}$, from nearest) **do**
        if $BWu_e \geq BWd_s$ **then**
          Add s to $\mathbf{L_{se}}$
          $BWu_e \leftarrow BWu_e - BWd_s$
          Remove s from $\mathbf{L_s}$
        end if
      end for
      if $BWu_e < minBW$ **then**
        Remove e from $\mathbf{L_e}$
      end if
    end for
  end for

Experimental scenario

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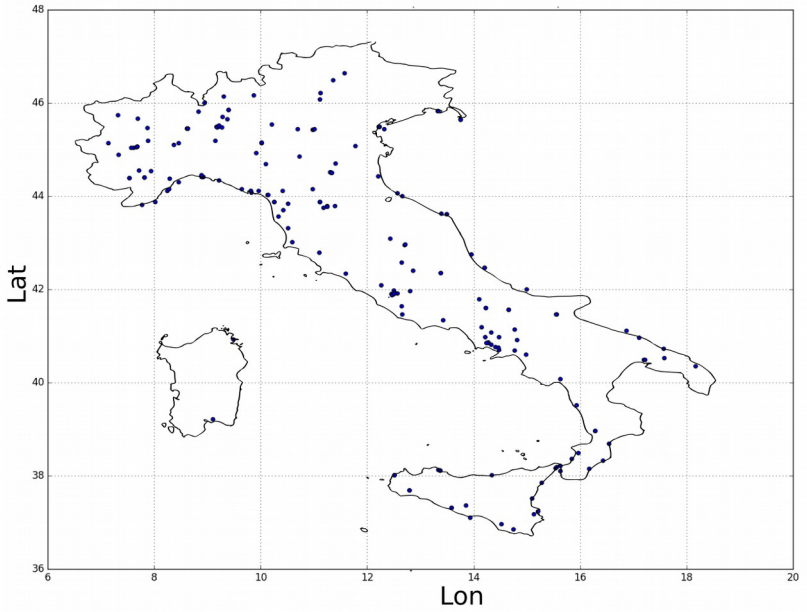
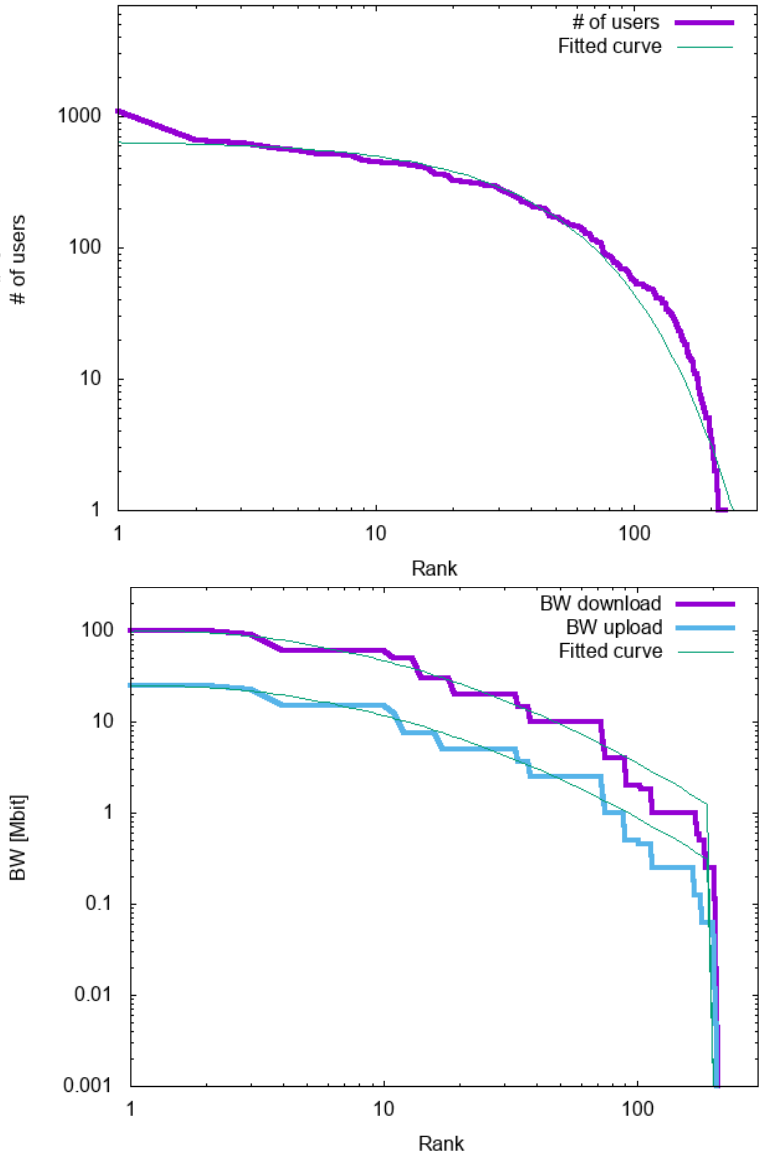
- Preliminary analysis of data
- Fitting with lognormal & exponential truncated distributions
- → No heavy tailed behavior





Experimental setup

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- Focus on live streaming scenario
- Locations with BW < 512Kb/s not considered
- 3 encodings for clients
  - LD: 512 Kb/s
  - SD: 1Mb/s
  - HD: 1.5 Mb/s
- Our HD is far from YouTube-like HD quality

P-CDN evaluation

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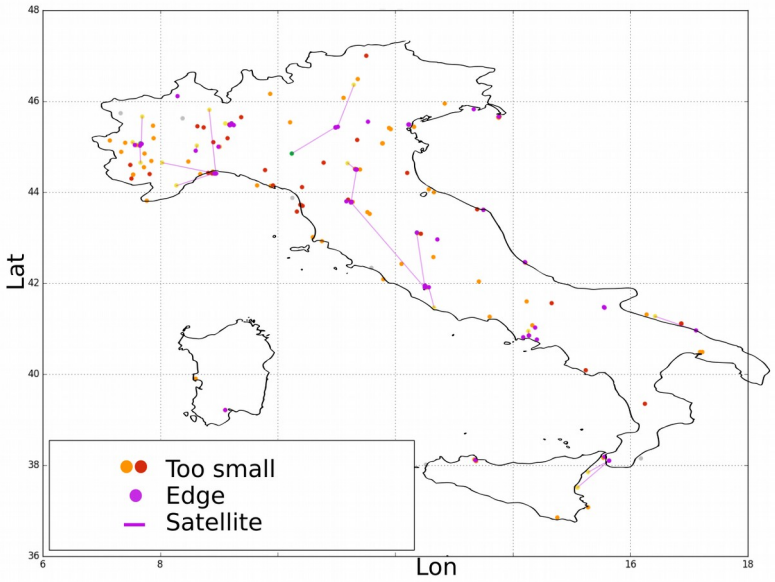
	P-CDN	No P-CDN
	# Locations	
Too small	99	0
Edge	77	0
Satellite	19	0
Origin	18	213
	# Clients	
LD	1577	1986
SD	94	94
HD	466	57



- HD clients: 57→466. Improvement > 7X
- Locations served by origin servers: 213→18+77. Drop > 55%

Sensitivity to *Thr* parameter

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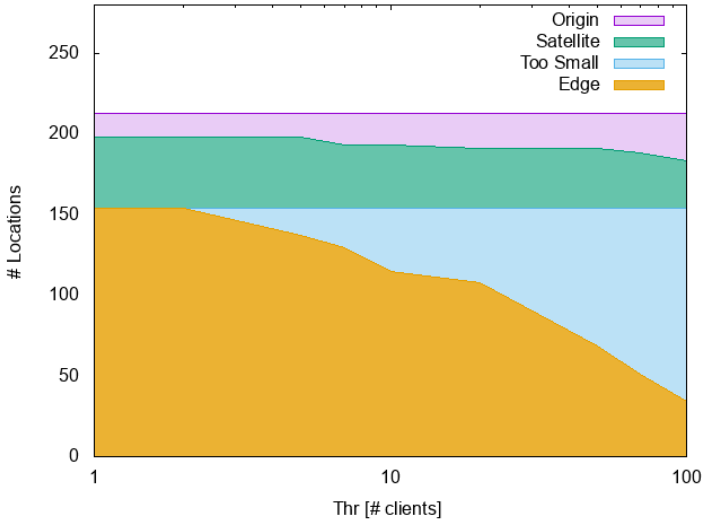
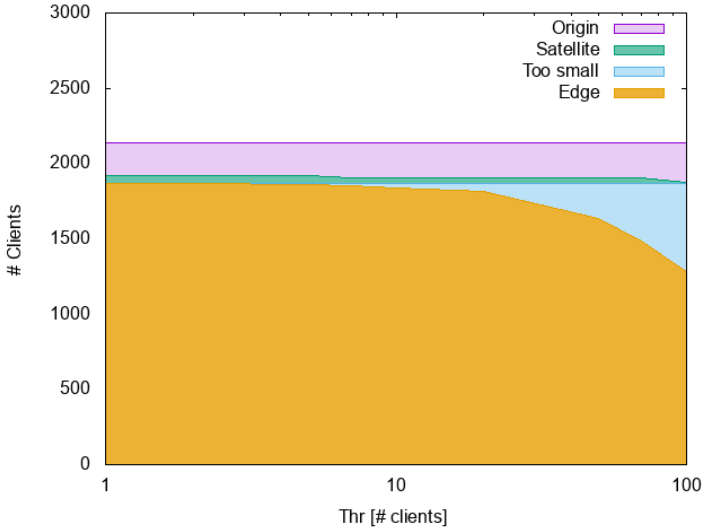
- Impact on locations (Thr grows)
  - *Too Small* locations grows
  - Satellite locations drops (less edge servers)
- Impact on clients (Thr grows)
  - Similar to locations
  - Effect less evident (impact on locations with few clients)





Sensitivity to *Thr* parameter

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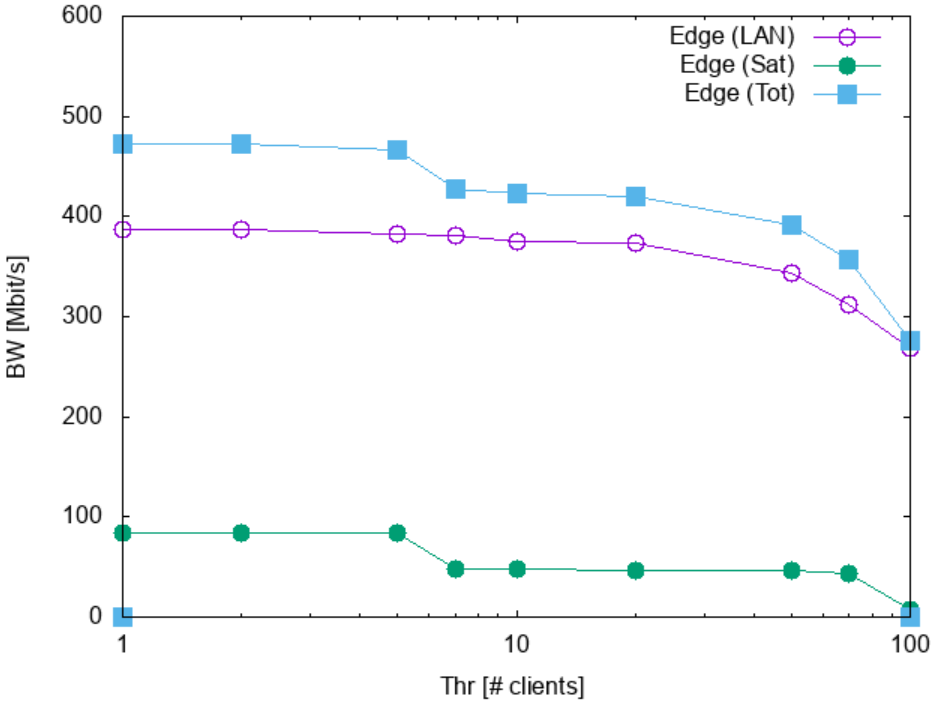
- Increasing Thr reduces the Edge server BW
- Satellite locations are a minor contribution
- Increasing Thr further reduces impact of satellites



Conclusions

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- Design of a Private CDN
  - Problem not discussed widely in literature
  - Specific constraints (workload & infrastructure)
- Proposal of formal model & heuristics
- Application to a case study (nationwide Italian company)
  - Positive impact of P-CDN infrastructure
  - High cost: need to keep low number of edge servers
  - BW may be an issue (low data rate for HD)

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