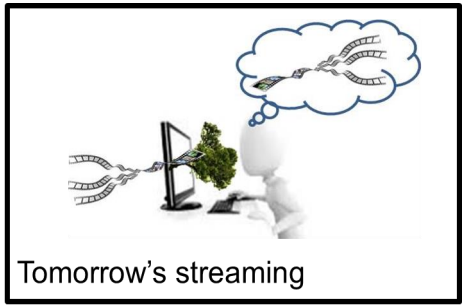
Delivering Tomorrow's Increasingly Interactive Streaming Services

Niklas Carlsson

Linköping University, Sweden

@ Students, May 20, 2020

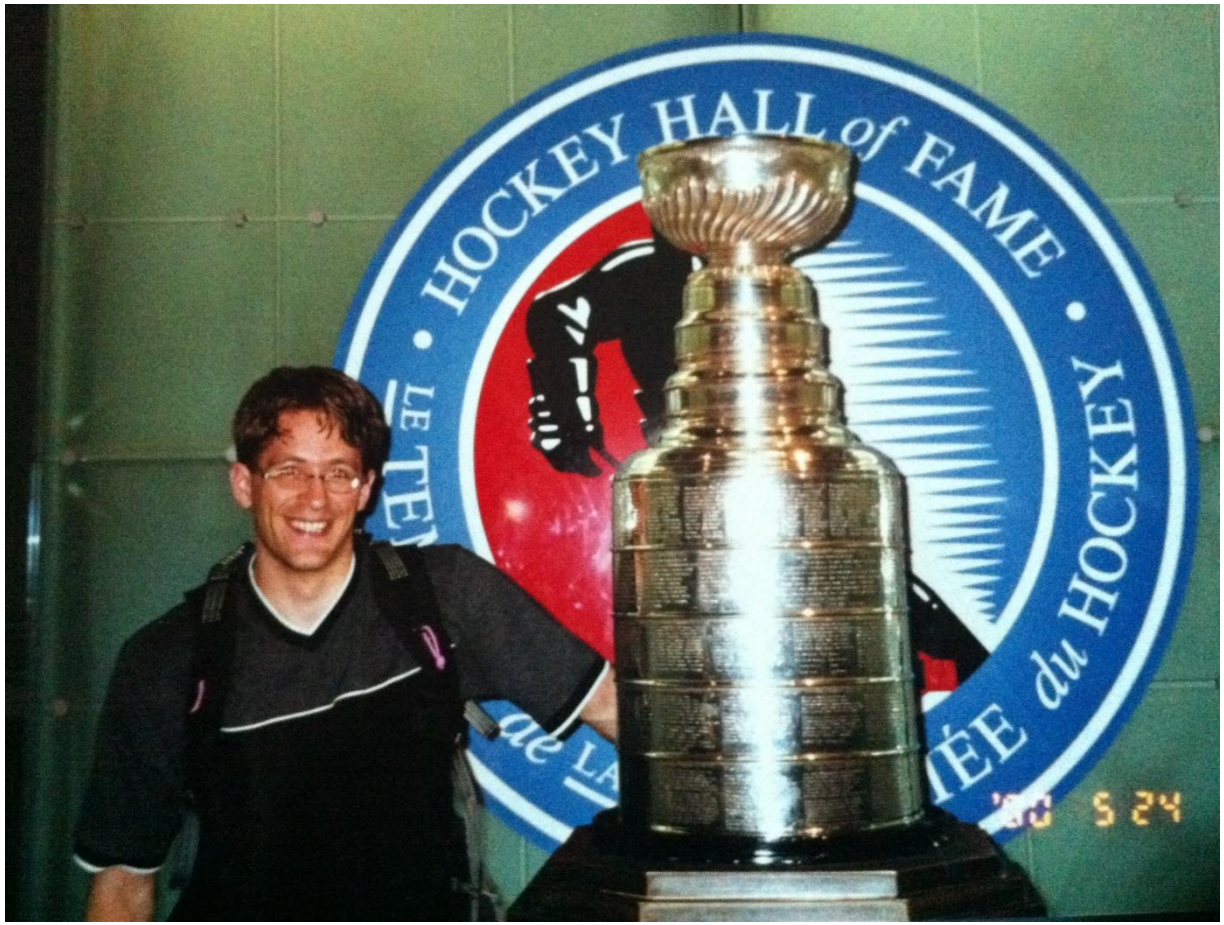
LINKÖPING UNIVERSITY



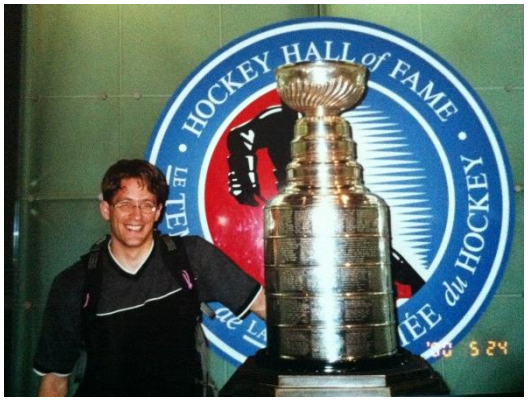
Much of the work here in collaboration ...

- ***Former PhD Students at LIU***
  - *Vengatanathan Krishnamoorthi (now at **Ericsson**)*
  - *Rahul Hiran (now at **Ericsson**)*
  - *Anna Vapen (now at Mindcamp)*
- ***Other research collaborators (alphabetic)**:*
  - *Martin Arlitt (HP Labs, USA)*
  - *Youmna Borghol (NICTA, Australia)*
  - *György Dan (KTH, Sweden)*
  - *Derek Eager (University of Saskatchewan, Canada)*
  - *Phillipa Gill (UMass, USA)*
  - *Ajay Gopinathan (Google, USA)*
  - *Emir Halepovic (AT&T research, USA)*
  - *Patrick Lambrix (LiU, Sweden)*
  - *Anirban Mahanti (NICTA, Australia)*
  - *Carey Williamson (University of Calgary, Canada)*
  - *... and more ...*

Before I start ...



Tomorrow's interactive services ...



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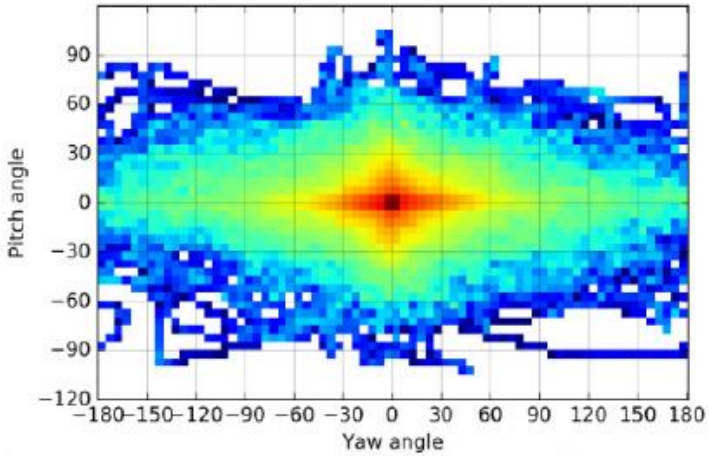

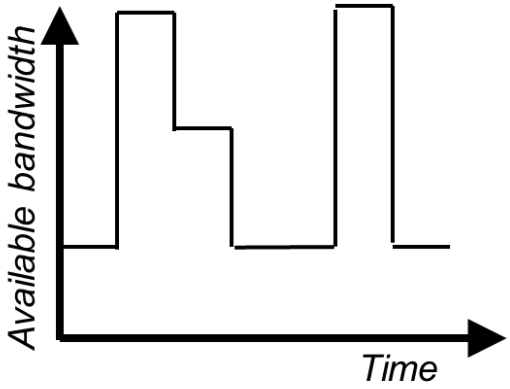

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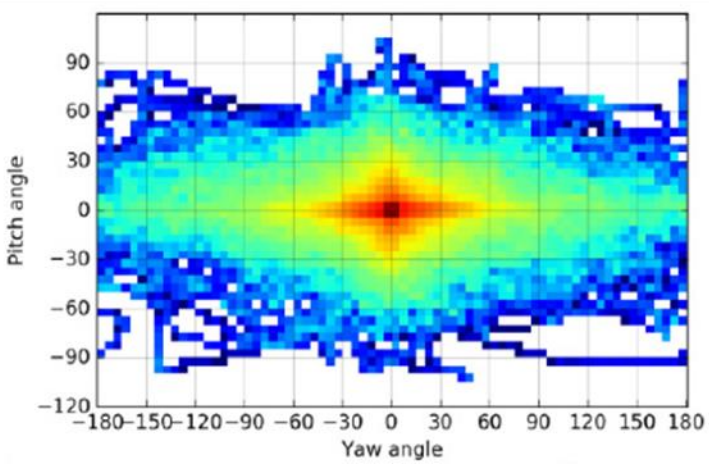

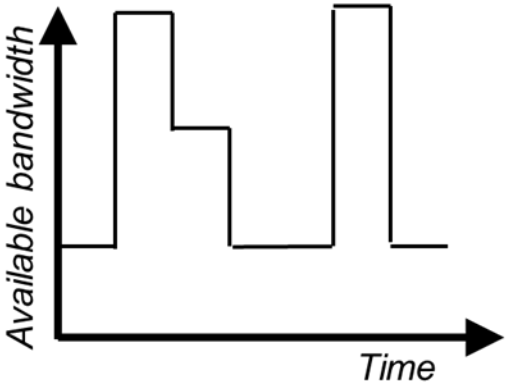

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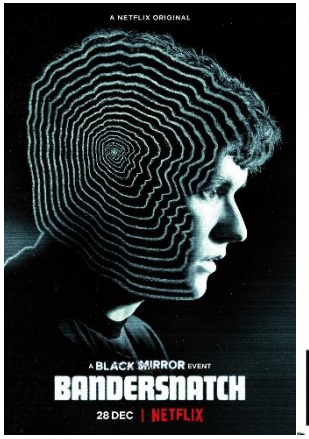

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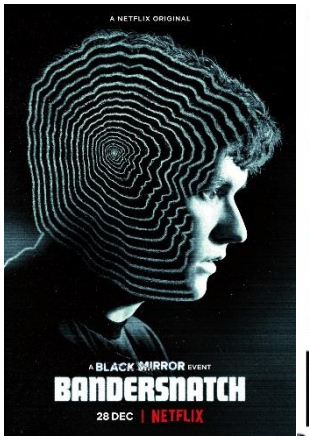
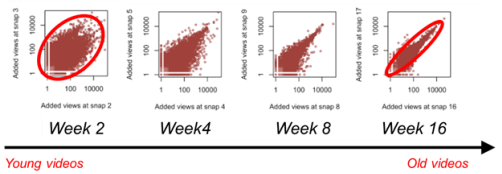


Research overview: Niklas Carlsson

Design, modeling, and performance evaluation of distributed systems and networks

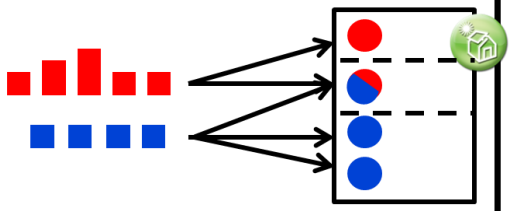

Tomorrow's streaming

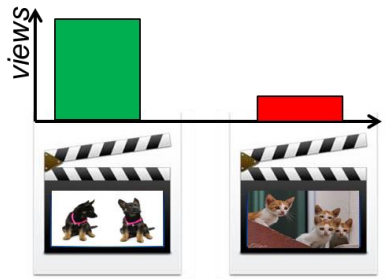

Scalable content delivery



Popularity dynamics

Network security


Efficiency and sustainability



Characterization, analytics, modeling

***Services**: E.g., content delivery and other distributed or networked services*

***Goals:** Better understand, model, design, optimize, and secure*

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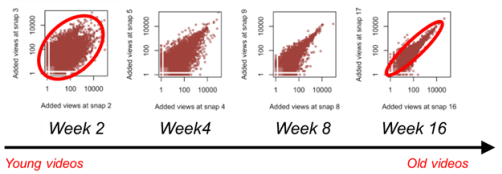

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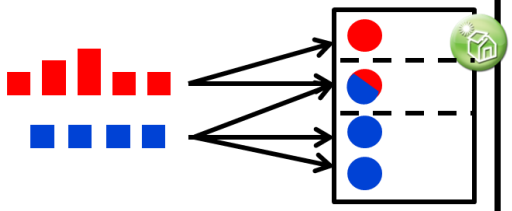
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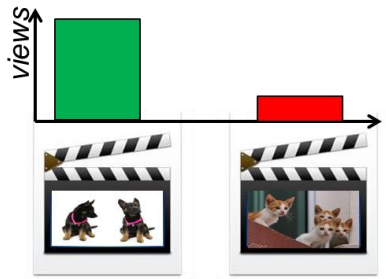

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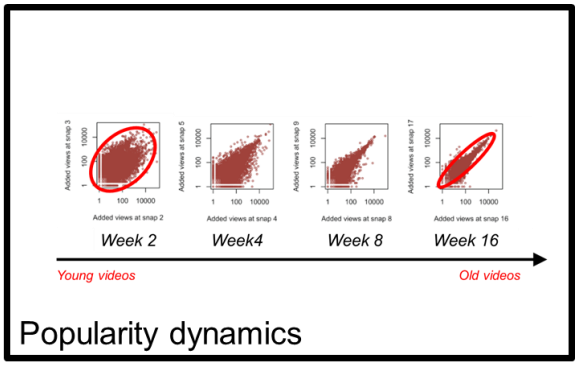

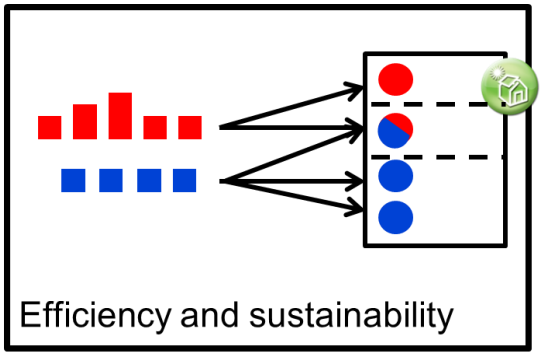

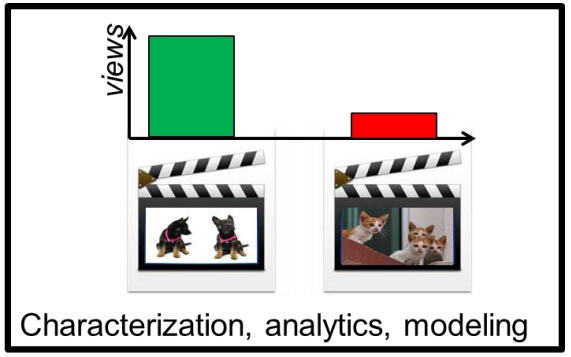

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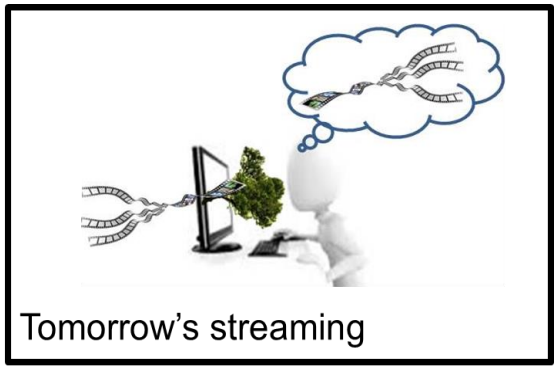

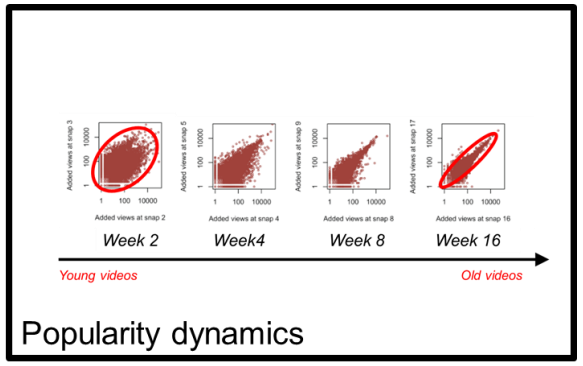

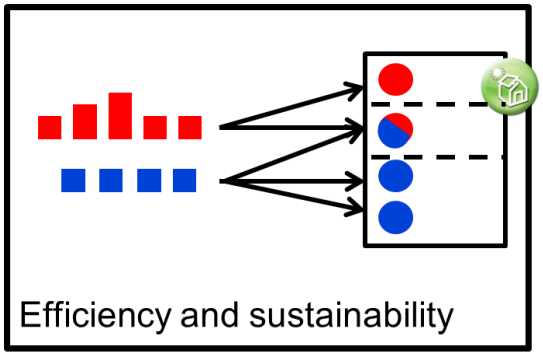

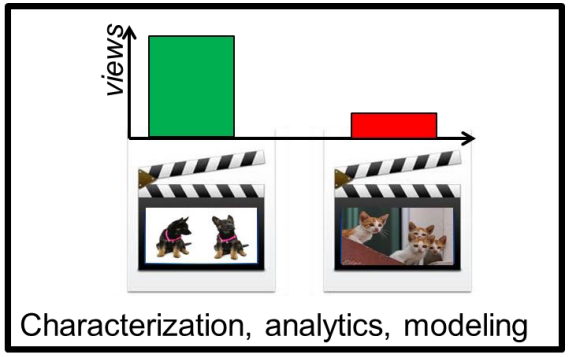

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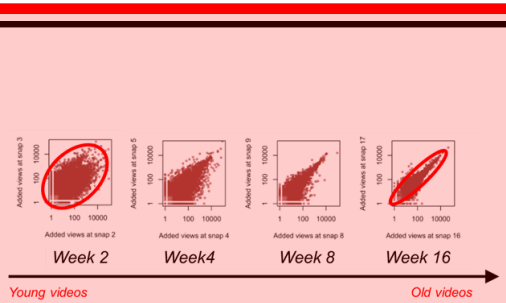
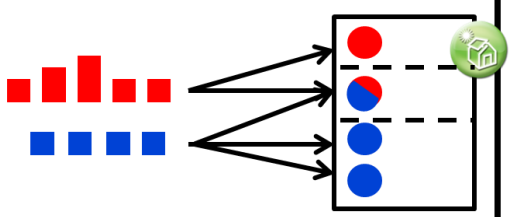
Tomorrow's streaming

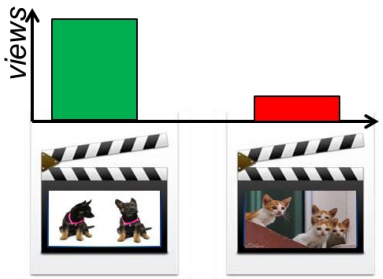

Scalable content delivery



Popularity dynamics

Network security


Efficiency and sustainability



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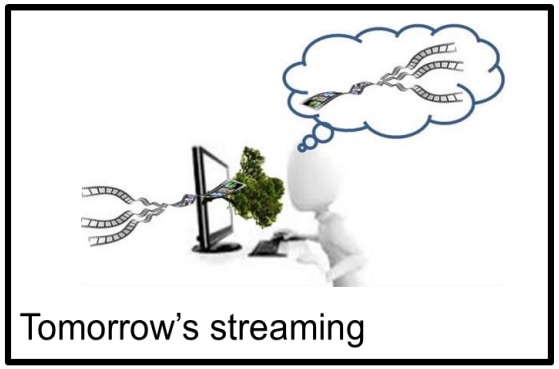

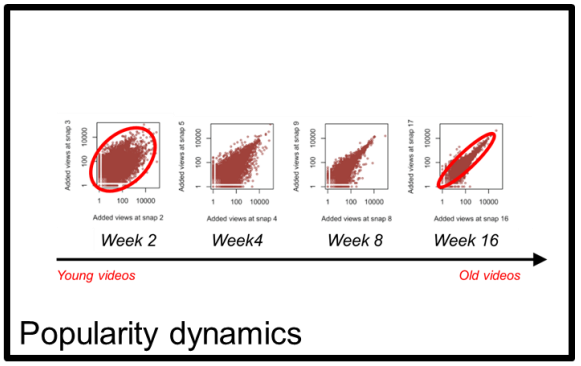

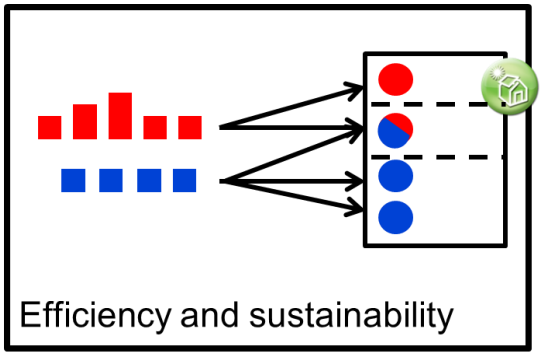

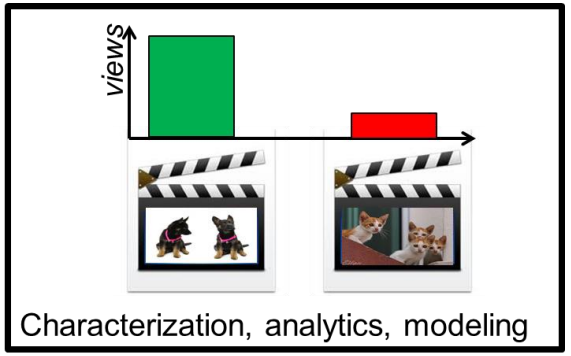

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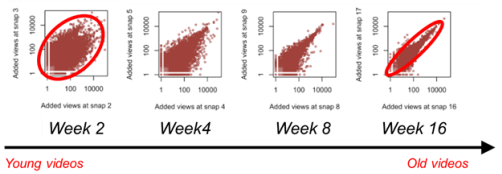

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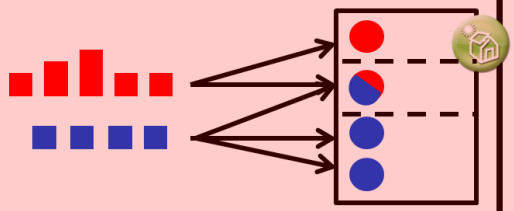
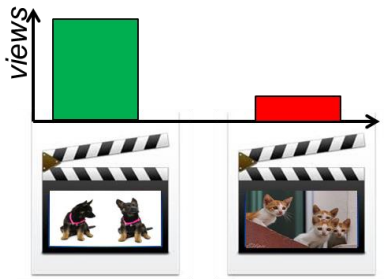

Efficiency and sustainability



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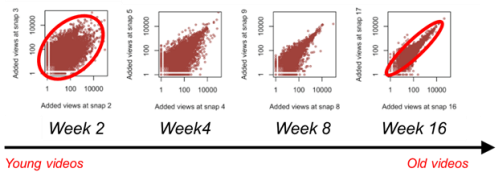

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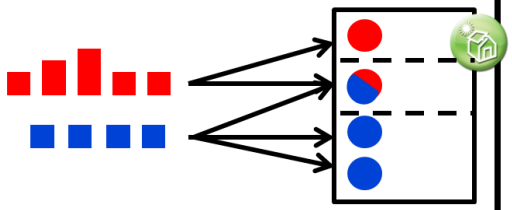
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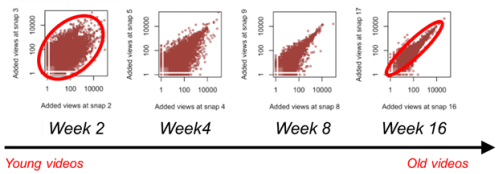

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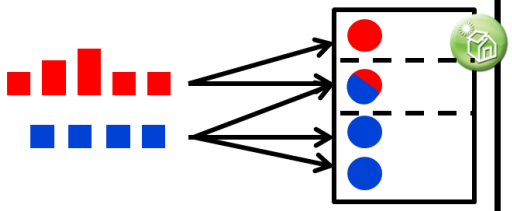
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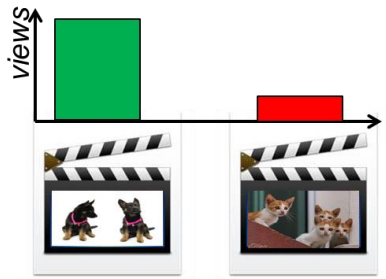

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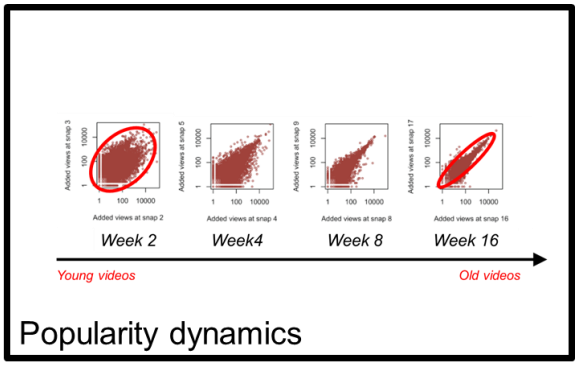

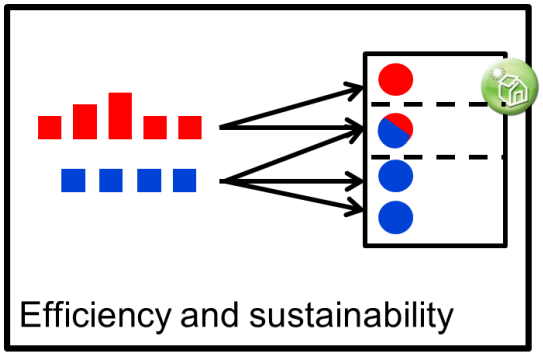

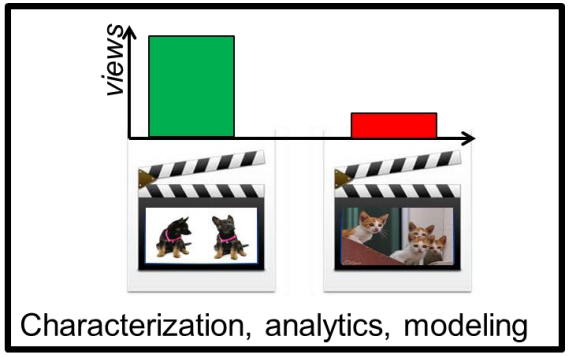

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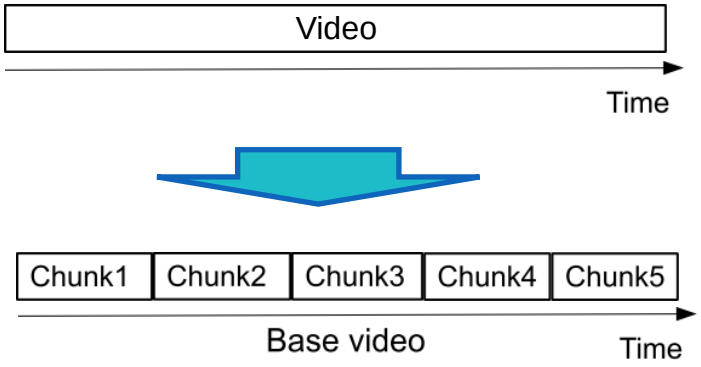
First some background …

Background:
HTTP-based Adaptive Streaming (HAS)



- HTTP-based streaming
  - Video is split into chunks
  - Support for VoD (Video on Demand) functionalities

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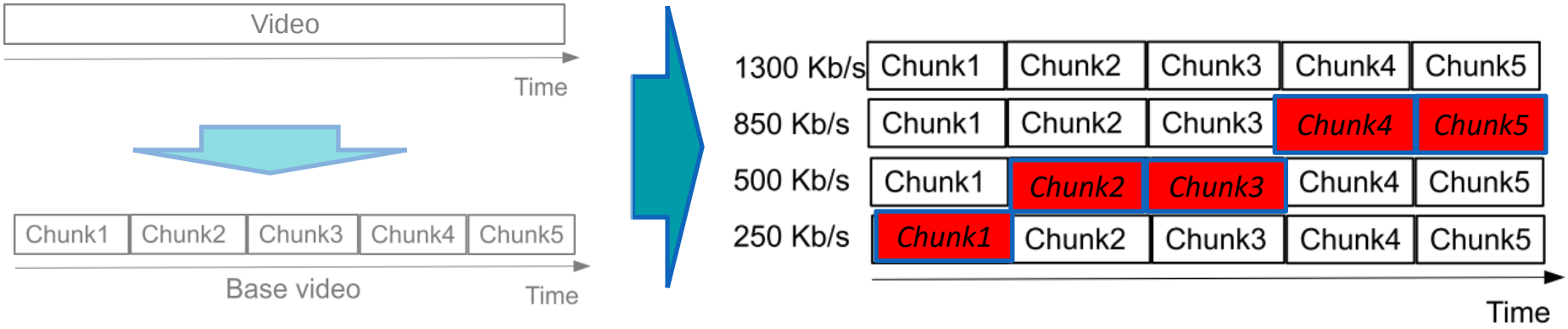


- HTTP-based streaming
  - Video is split into chunks
  - Support for VoD (Video on Demand) functionalities
- HTTP-based adaptive streaming
  - Each chunk in multiple bitrates (qualities)
  - Clients adapt quality encoding based on buffer/network conditions

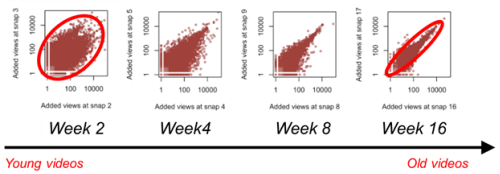
Example research to address the aforementioned problem include …

Research overview

Design, modeling, and performance evaluation of distributed systems and networks

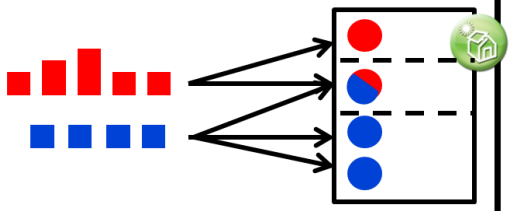

Tomorrow's streaming

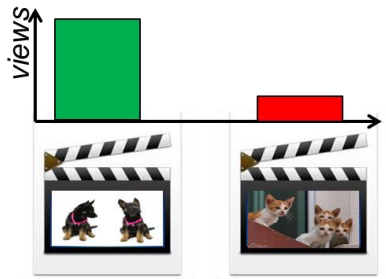

Scalable content delivery



Popularity dynamics

Network security


Efficiency and sustainability



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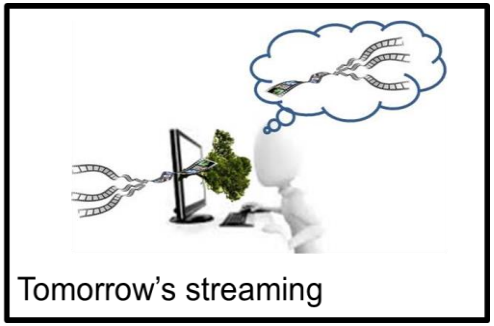
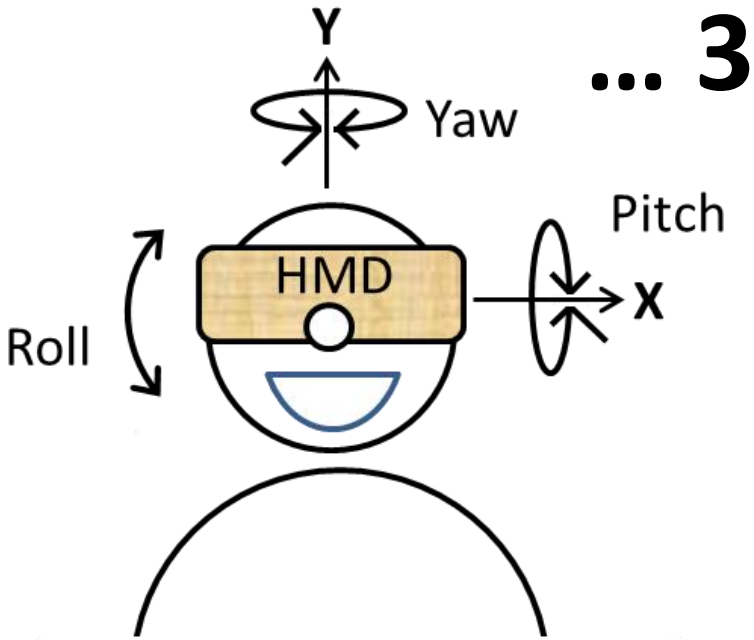
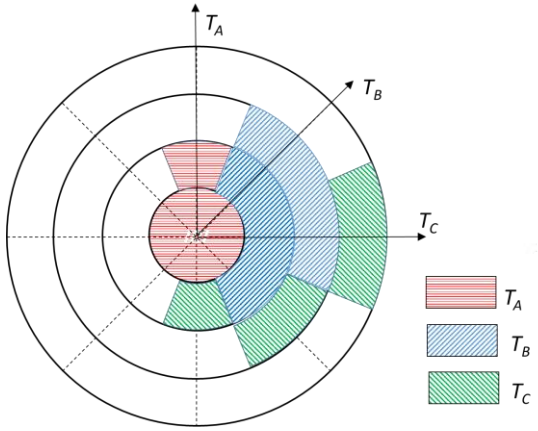
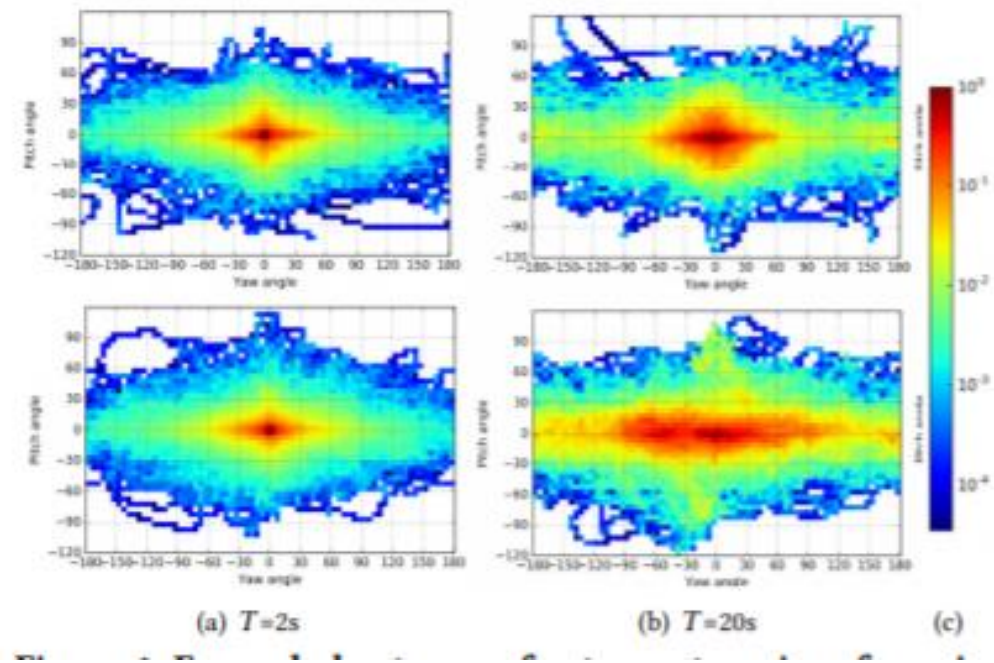


… 360 video …

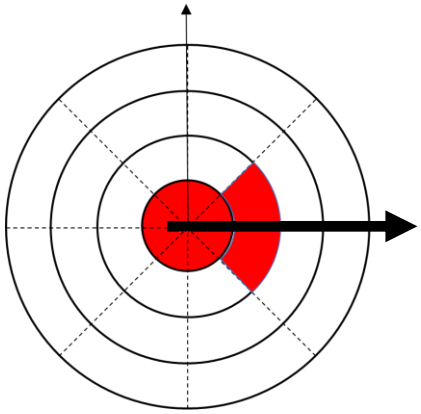






ACM MMSys 2018

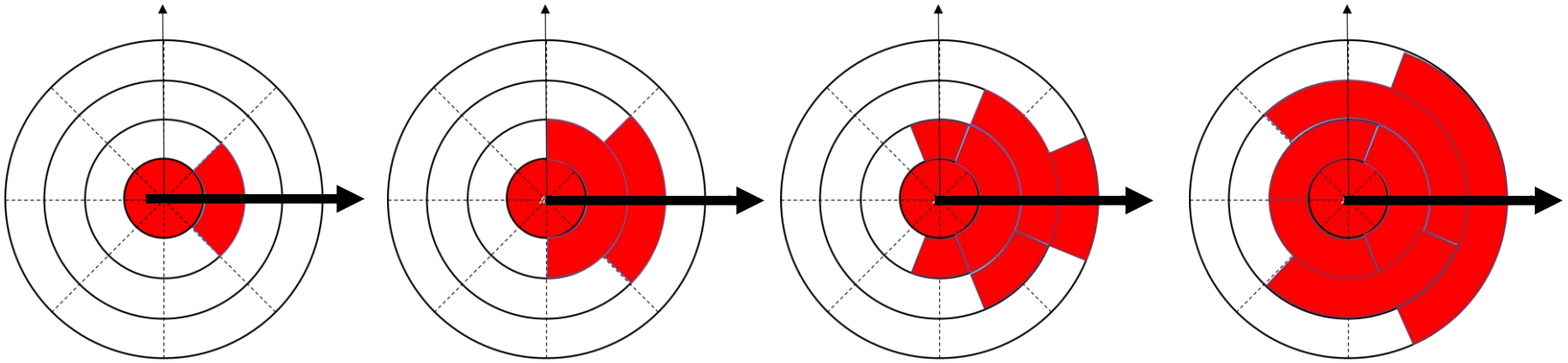
360 HAS with tiles



“Chunk 1”

- In addition to chunks, we have
  - Tiles of different quality in each direction
-
  -
  -

360 HAS with tiles

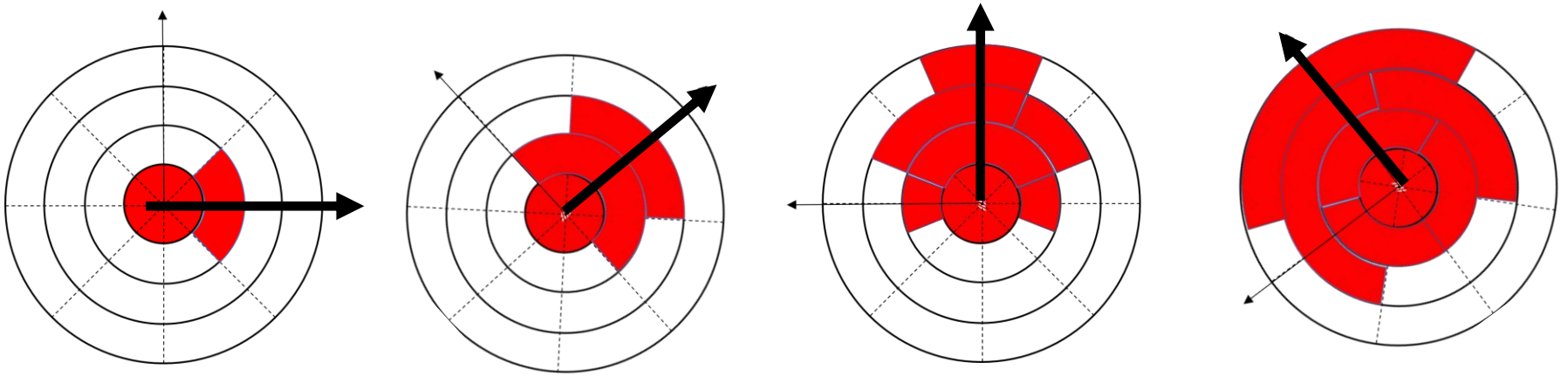


“Chunk 1” “Chunk 2” “Chunk 3” “Chunk 4”

- In addition to chunks, we have
  - Tiles of different quality in each direction

- Clients adapt quality encoding of each chunk and tile based on **both**
  - buffer/network conditions, and
  - expected view field

360 HAS with tiles



“Chunk 1” “Chunk 2” “Chunk 3” “Chunk 4”

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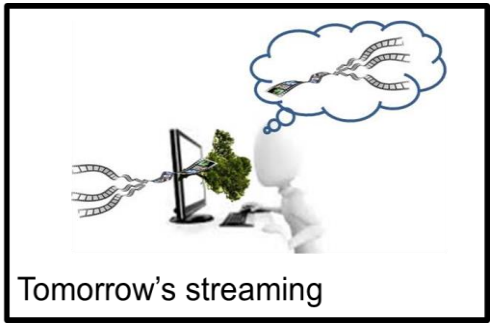
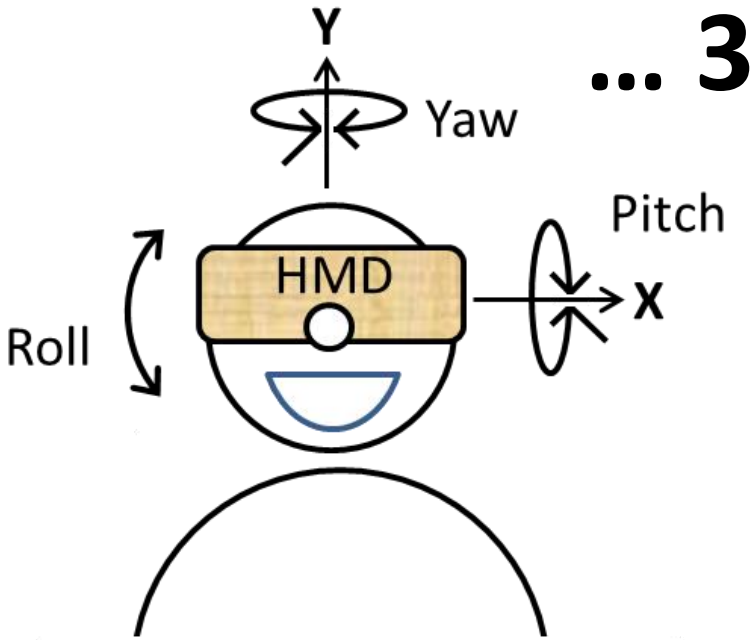
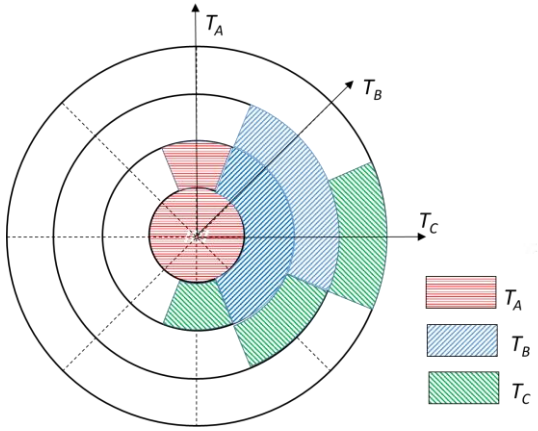
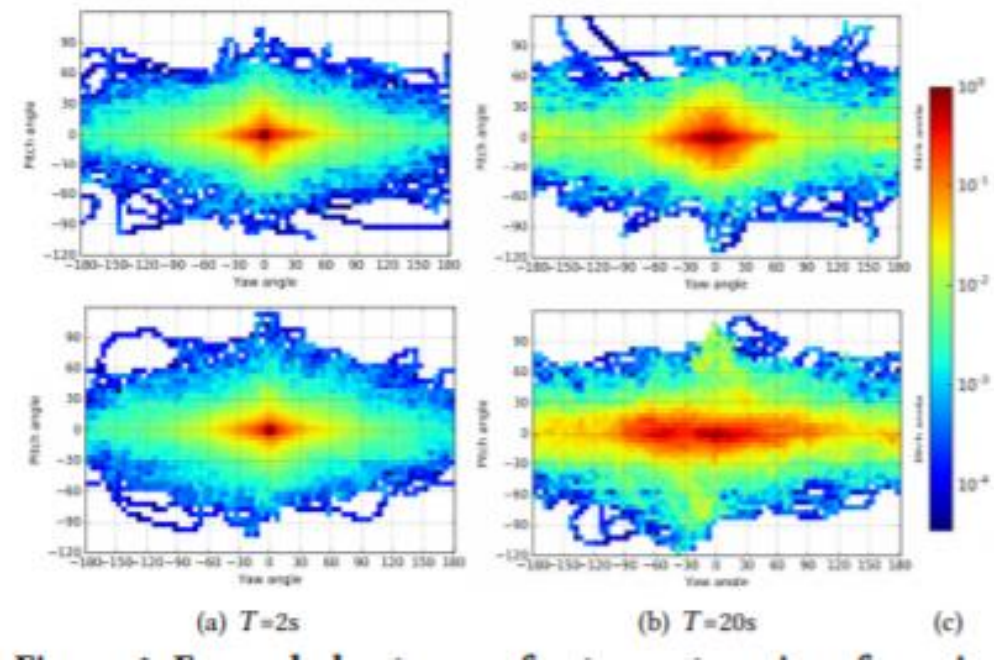


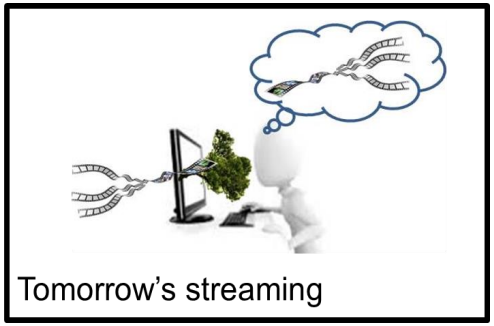
… 360 video …



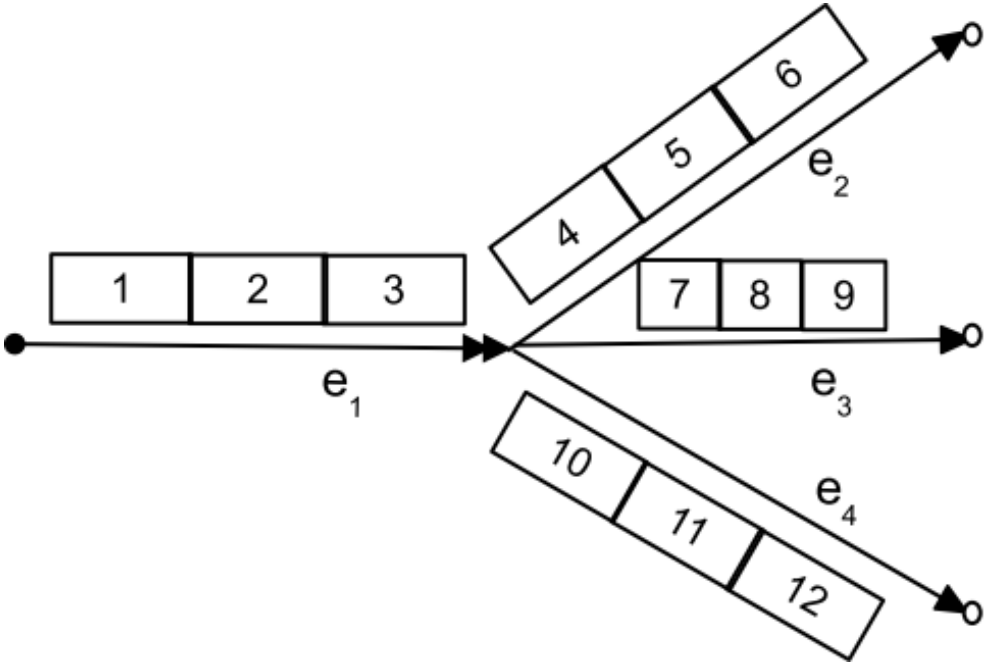


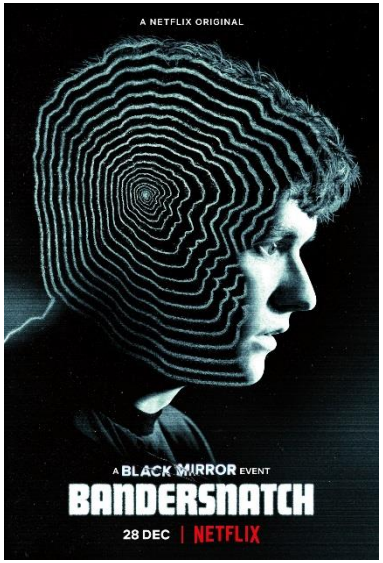


ACM MMSys 2018



… branched video …

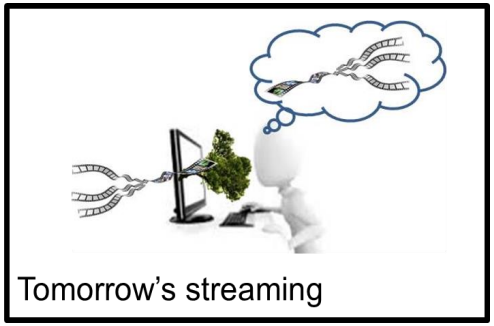




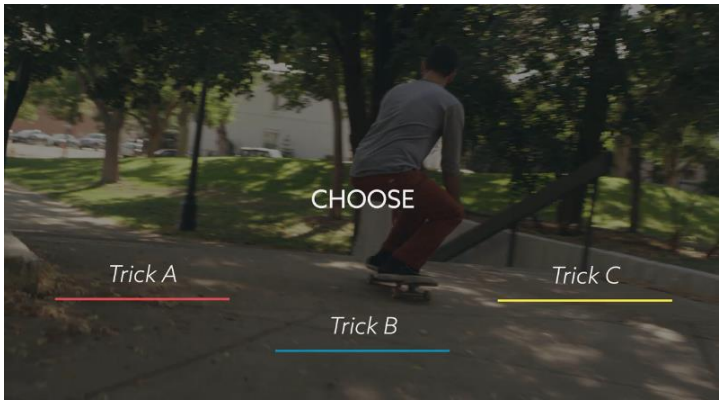
ACM MM 2019

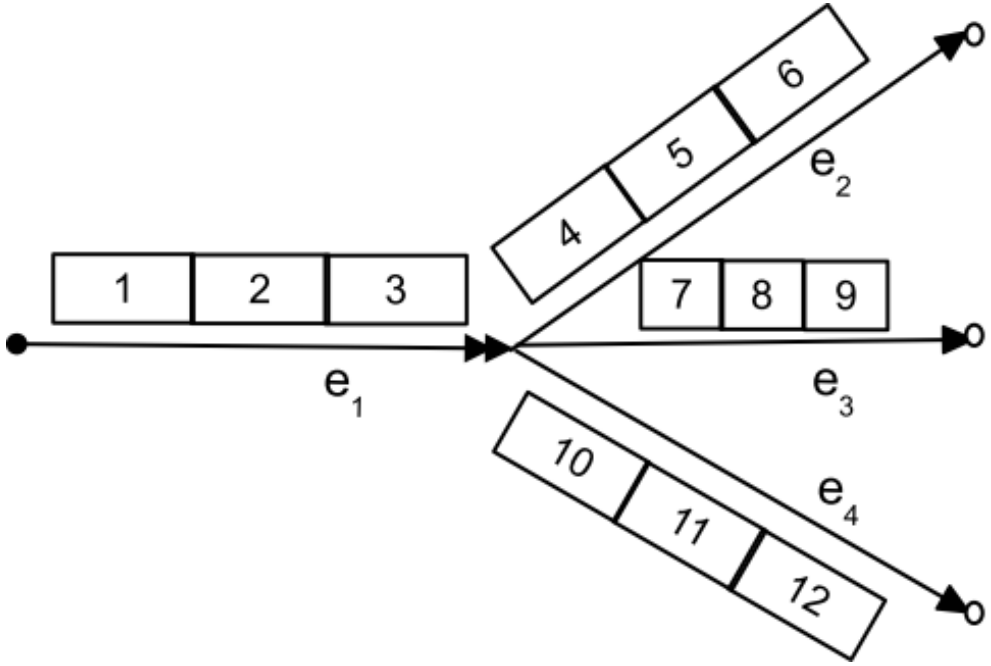
ACM MM 2014

ACM CCR 2013



… branched video …

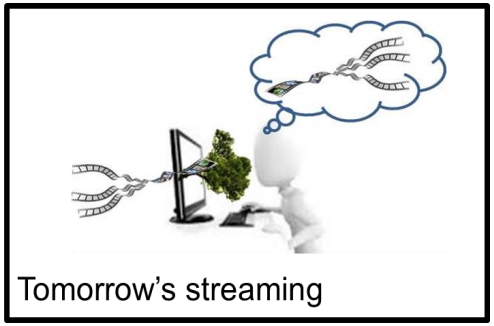




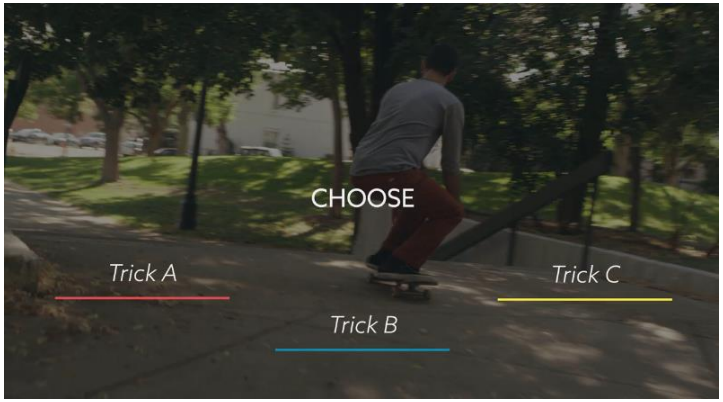
ACM MM 2019

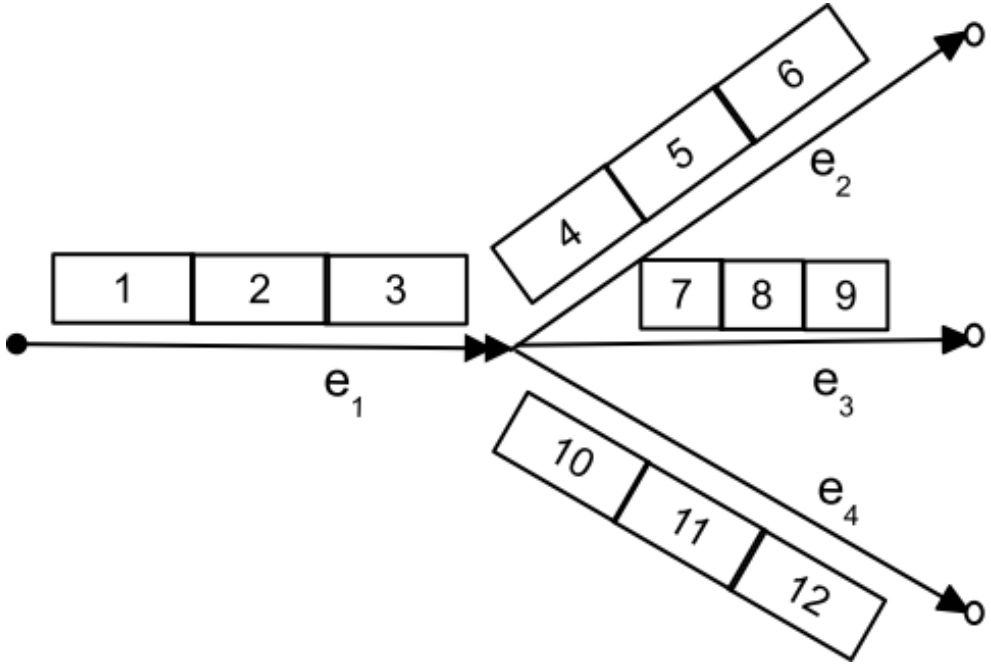
ACM MM 2014

ACM CCR 2013



… branched video …

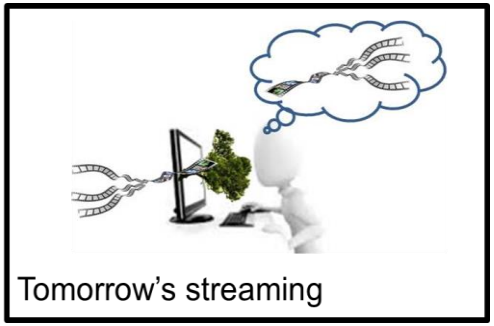




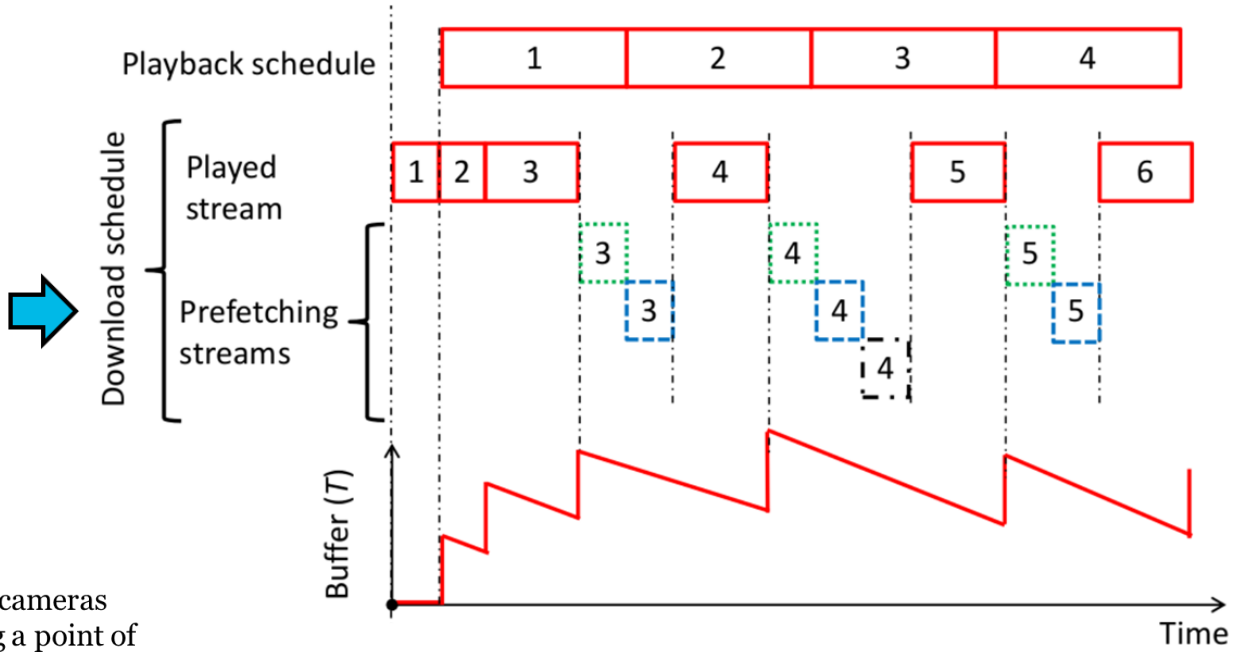
ACM MM 2019

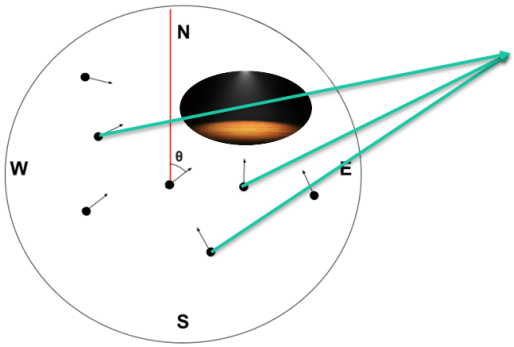
ACM MM 2014

ACM CCR 2013



… stream bundles …





Multiple cameras capturing a point of interest

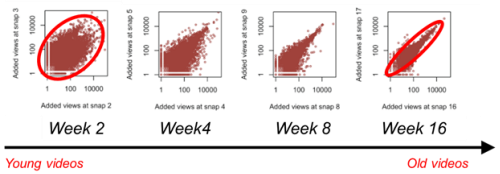
IEEE TMM 2017

Research overview

Design, modeling, and performance evaluation of distributed systems and networks

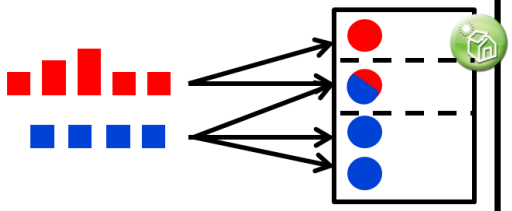

Tomorrow's streaming

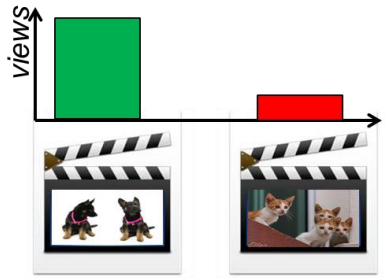

Scalable content delivery



Popularity dynamics

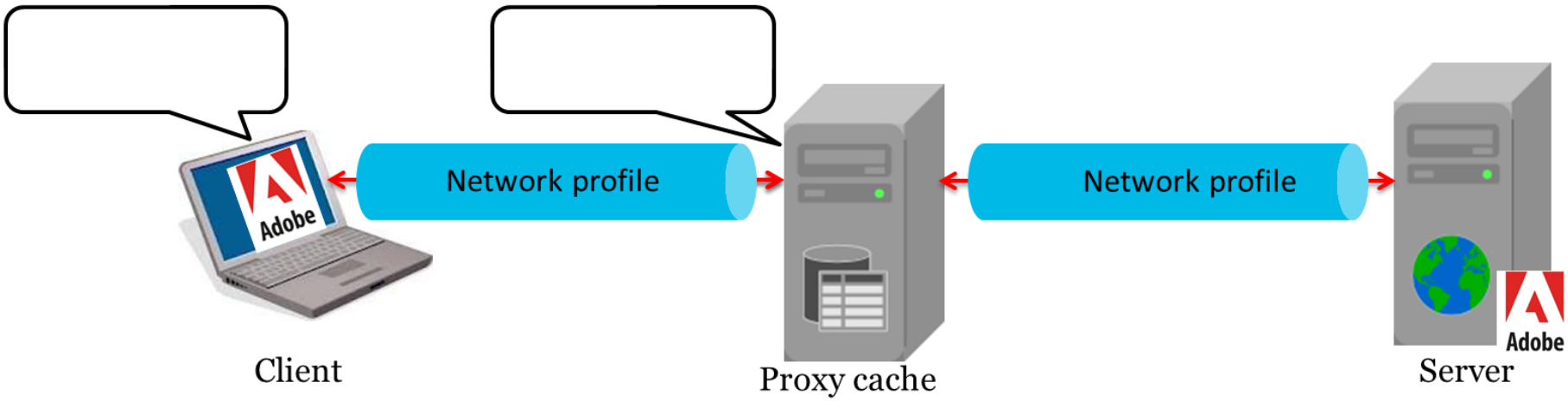
Network security


Efficiency and sustainability



Characterization, analytics, modeling

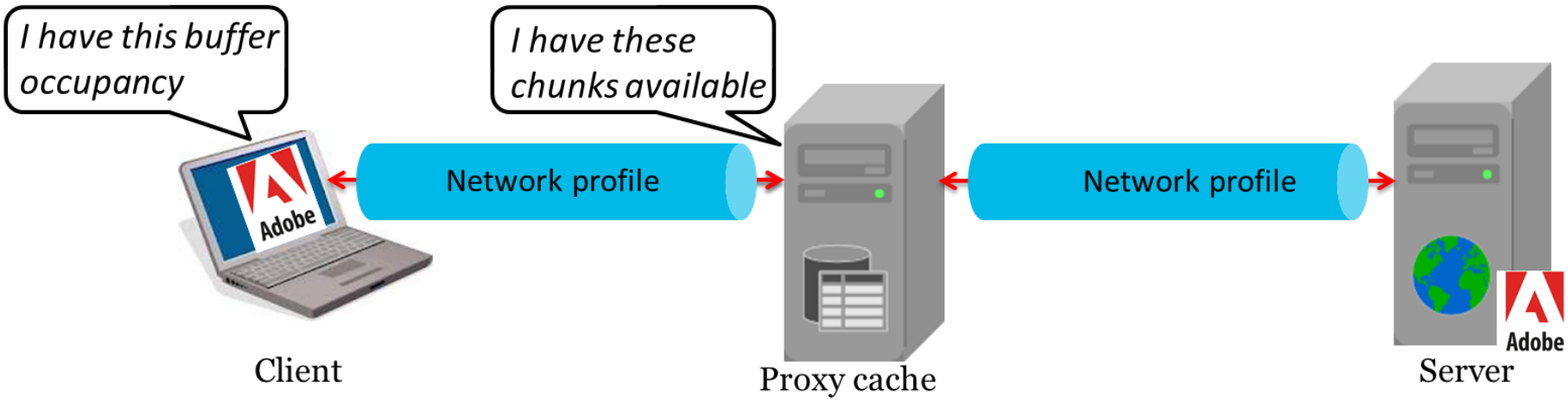
… HAS/DASH-aware proxies …



IEEE/ACM MASCOTS 2013

arXiv 2019

… HAS/DASH-aware proxies …



IEEE/ACM MASCOTS 2013

arXiv 2019

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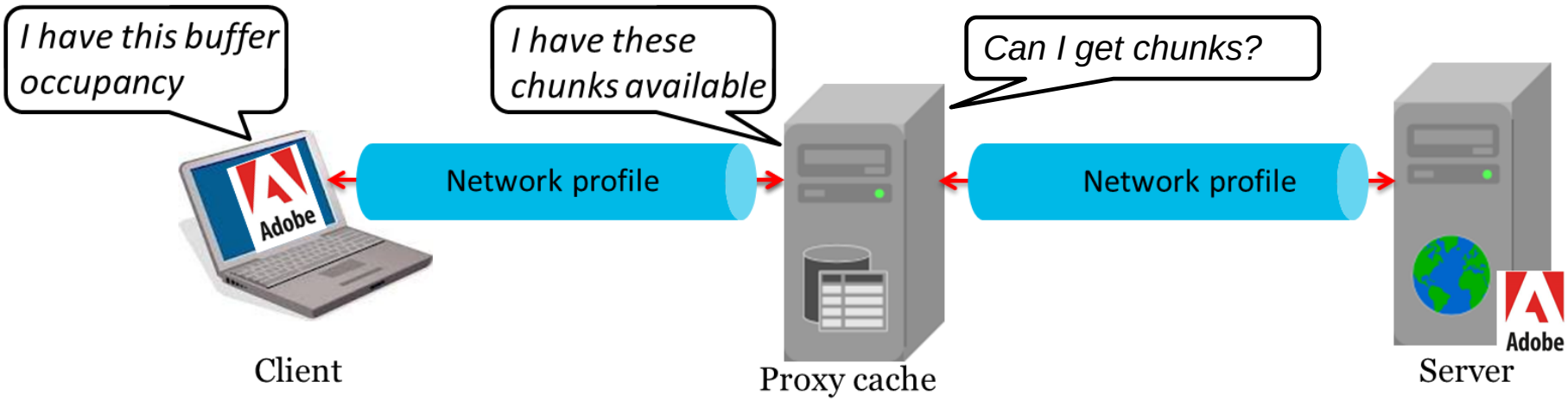
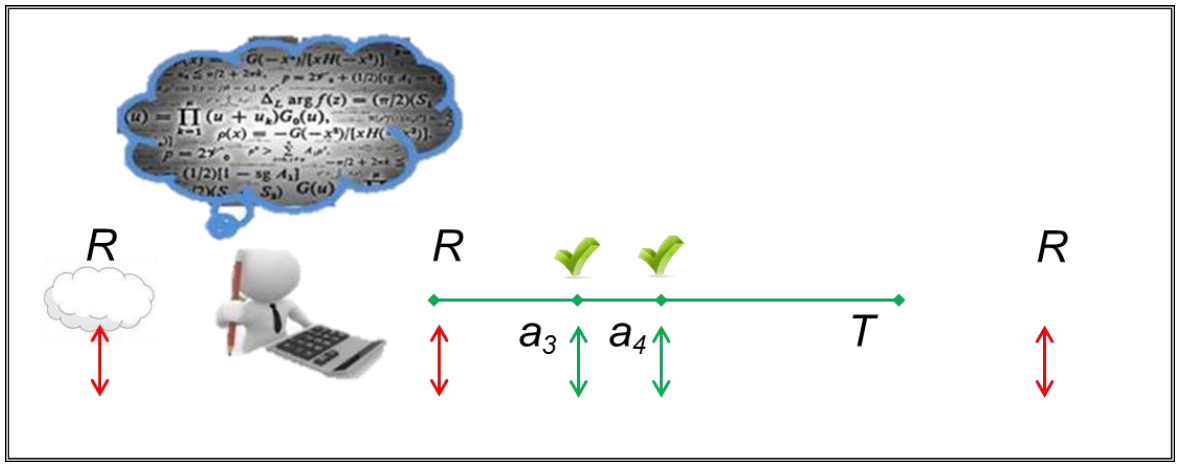


IEEE/ACM MASCOTS 2013

arXiv 2019

… to cache or not to cache (optimal caching policies under “elastic” conditions)…



IEEE TPDS 2017

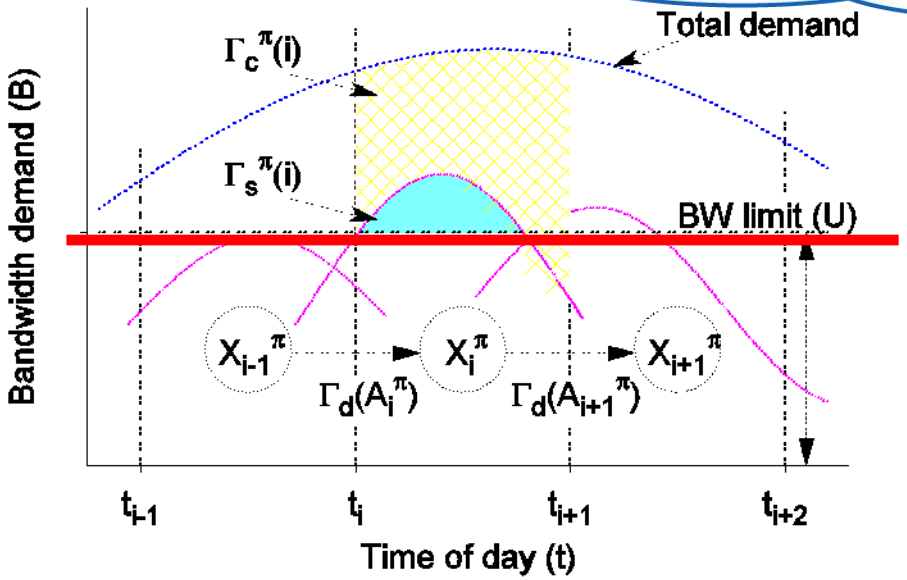
IFIP Performance 2018


Scalable content delivery

… cost-efficient delivery …

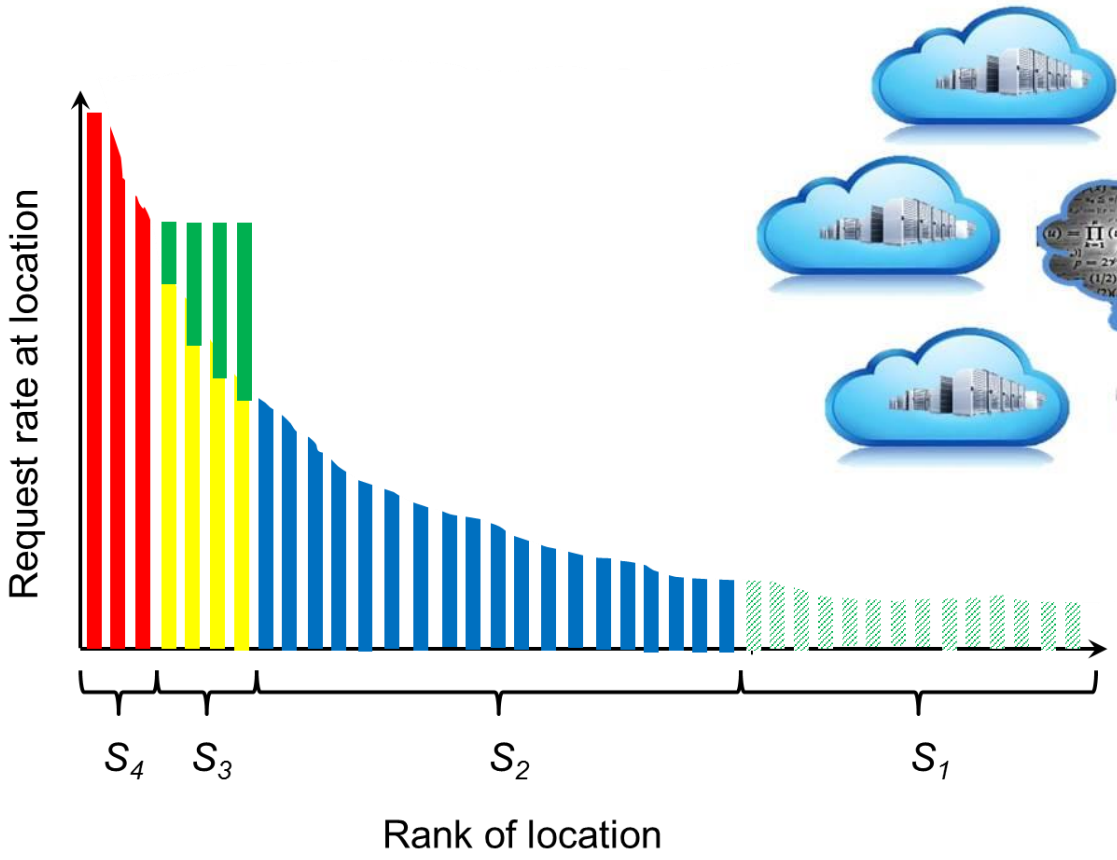
	Bandwidth	Cost
Cloud-based	Elastic/flexible	$$$
Dedicated servers	Capped	$

How to get the best of two worlds?

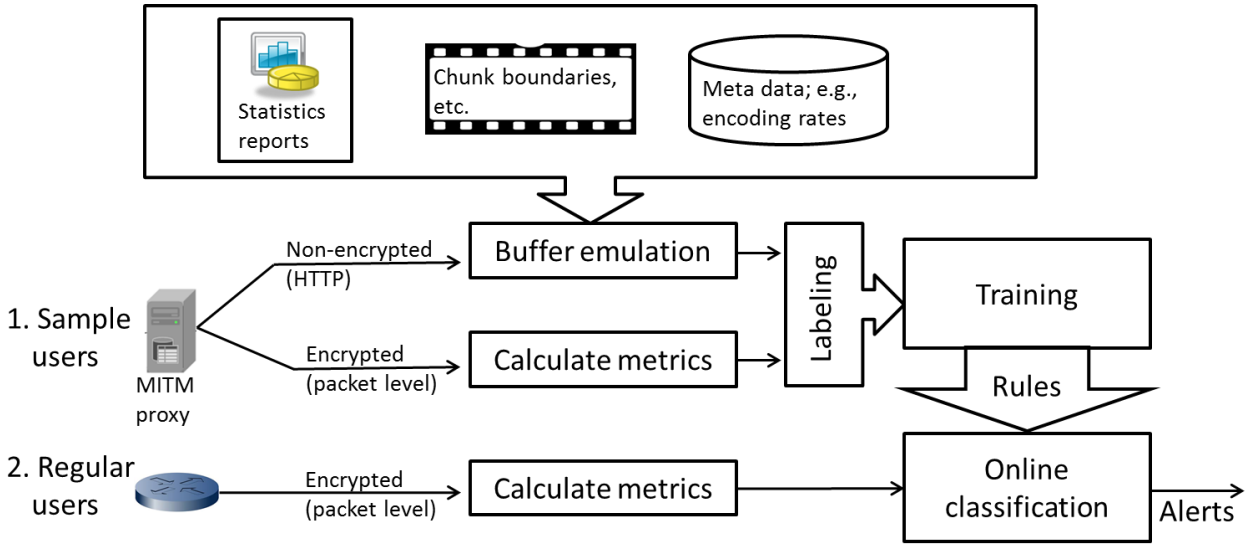


IEEE INFOCOM 2014

… determine who should serve who ...

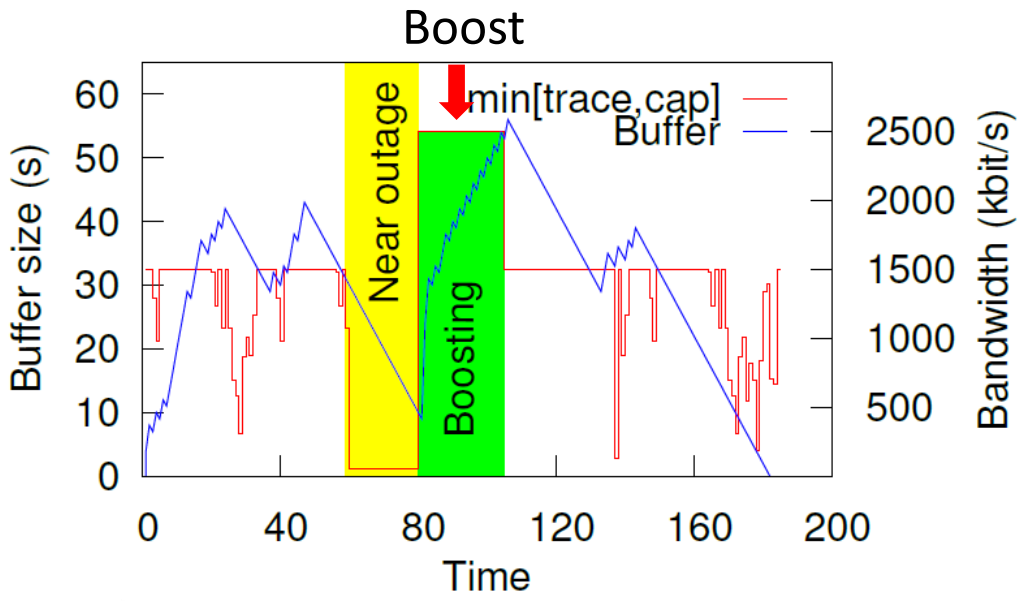


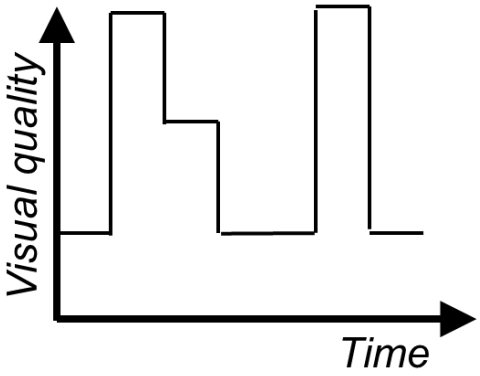
… BUFFEST …

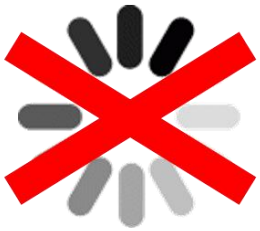


ACM MMSys 2017

… cap-based optimizations …





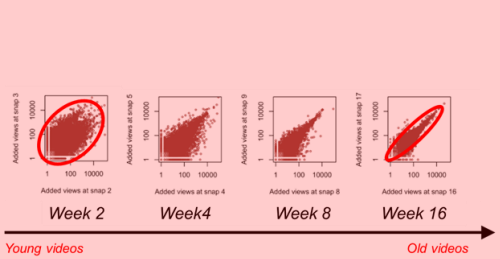


Research overview

Design, modeling, and performance evaluation of distributed systems and networks

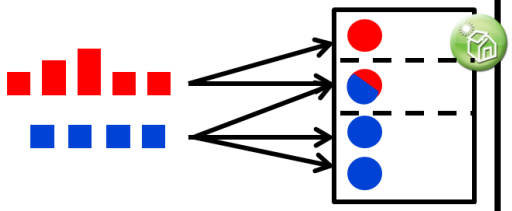

Tomorrow's streaming

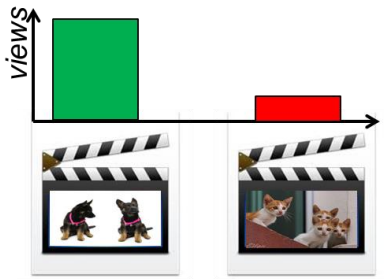

Scalable content delivery



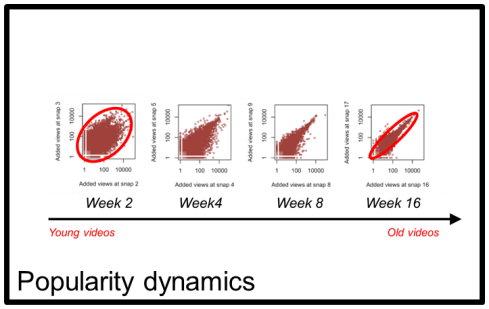
Popularity dynamics

Network security

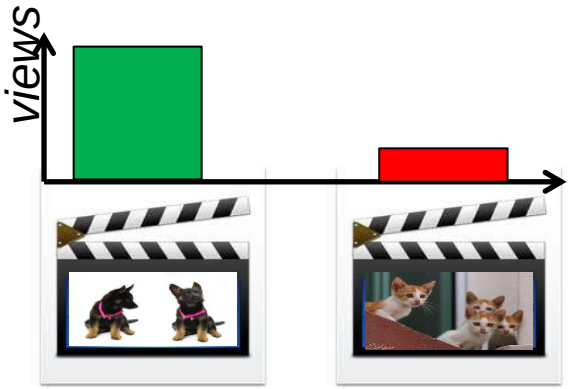

Efficiency and sustainability

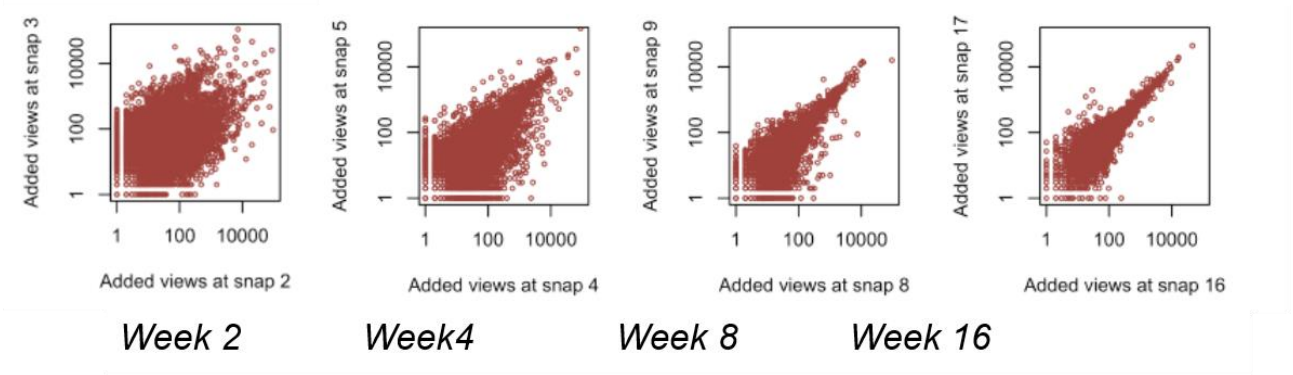


Characterization, analytics, modeling



… model+understand popularity …



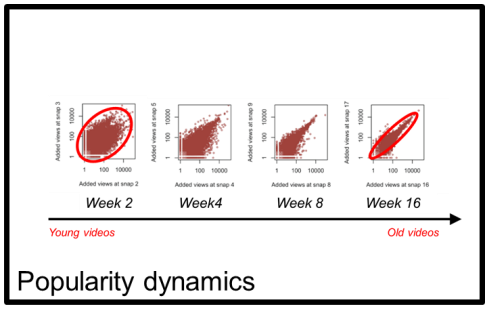


Young videos

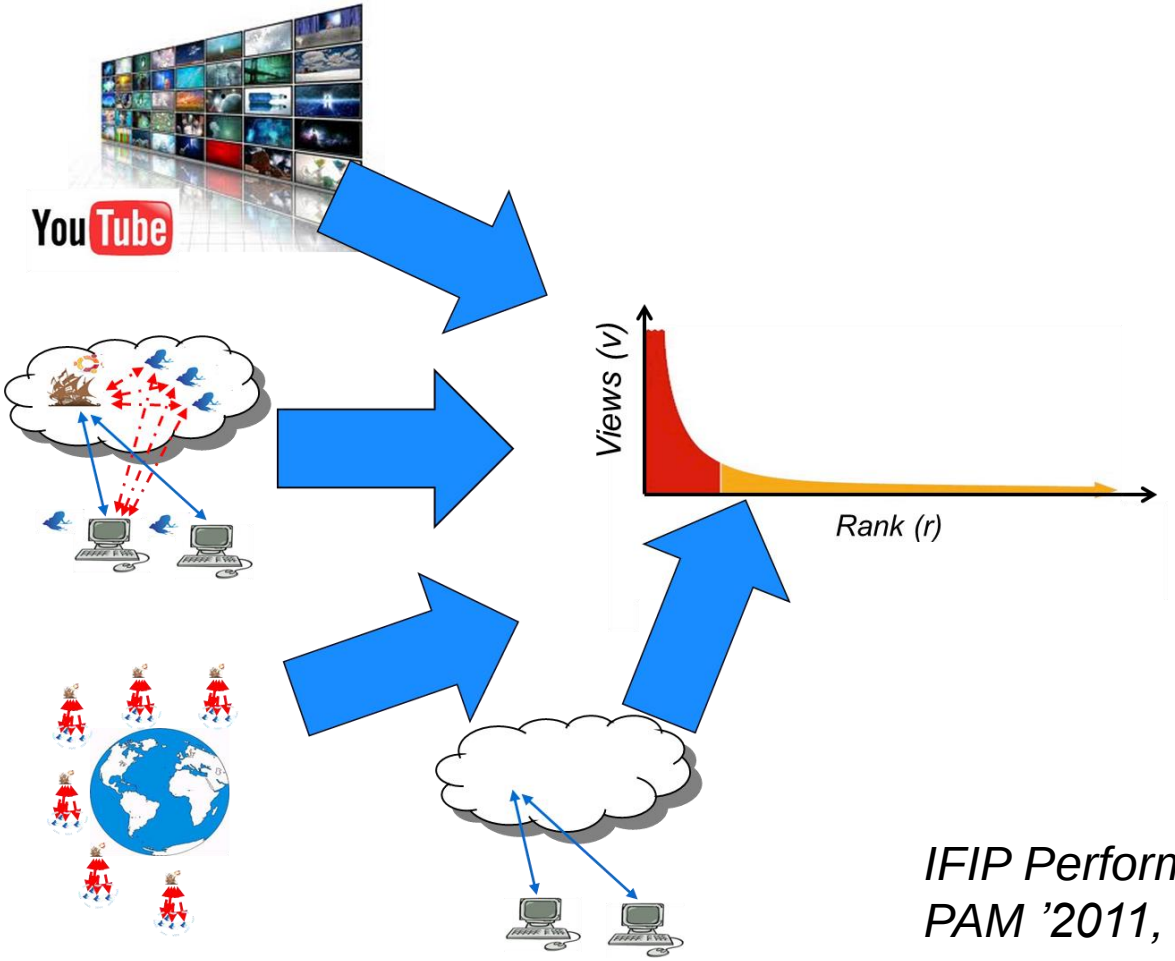
Old videos

ACM KDD 2012

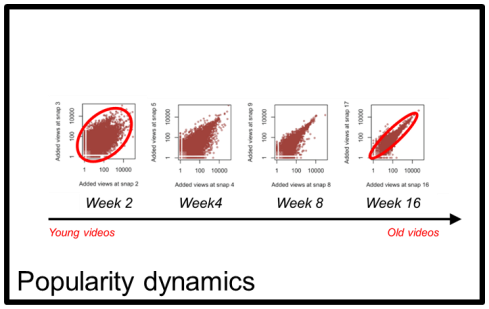
IFIP Performance 2011



… popularity dynamics and tails …

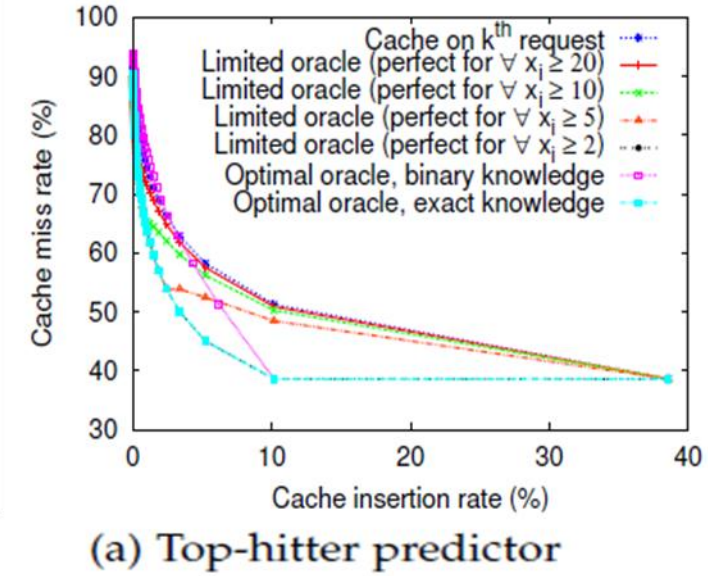


IFIP Performance 2011, IPTPS 2010, PAM '2011, 2 x ACM TWEB 2011, IEEE Network 2013, ...

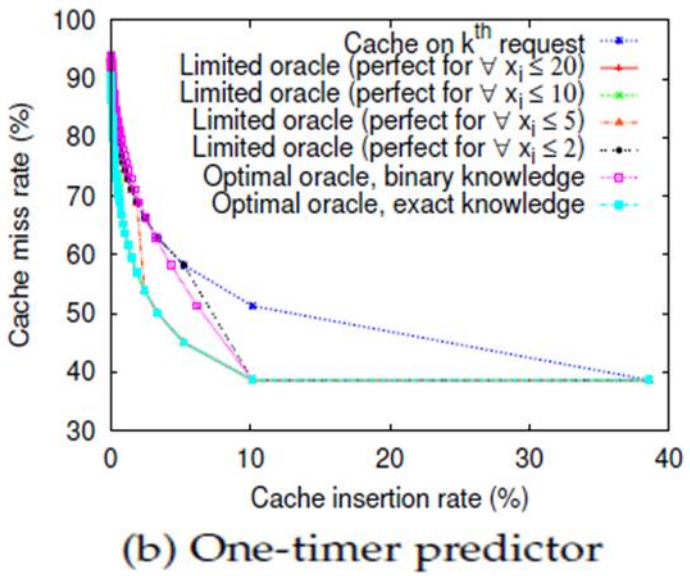


Popularity dynamics

… long tails and caching …

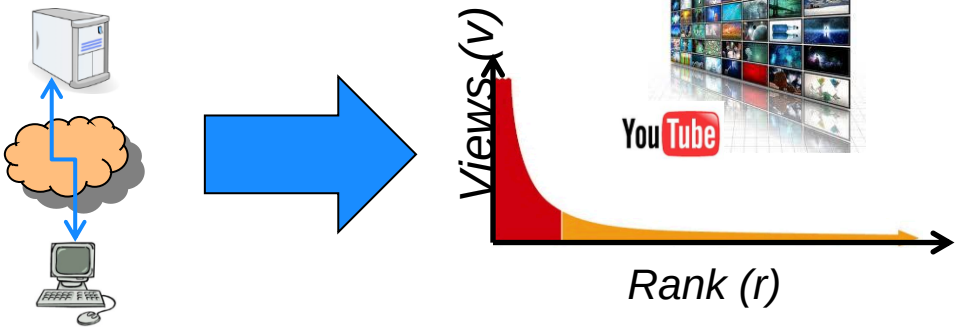


(a) Top-hitter predictor



(b) One-timer predictor

Fi



IEEE TPDS 2017

IFIP Performance 2018

(arXiv 2018, …)

… and some brief examples from the final three categories …

Research overview

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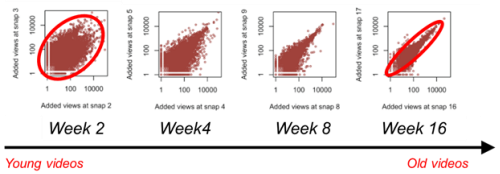
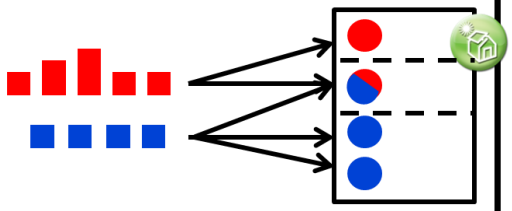
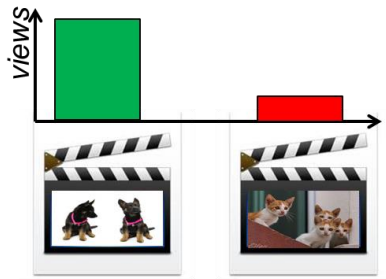
Scalable content delivery



Popularity dynamics

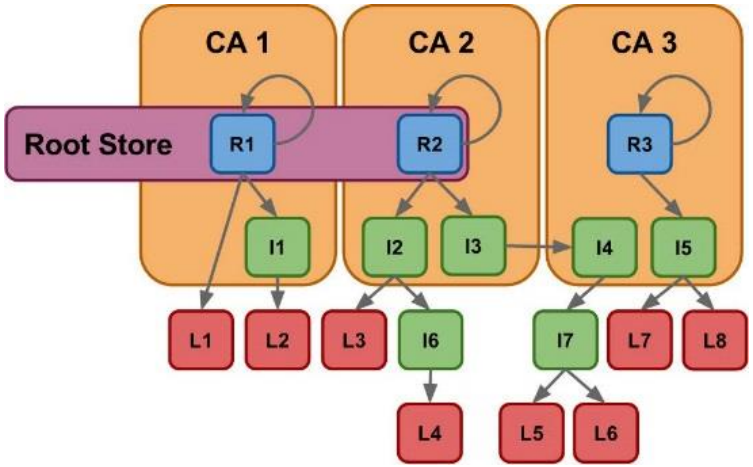
Network security

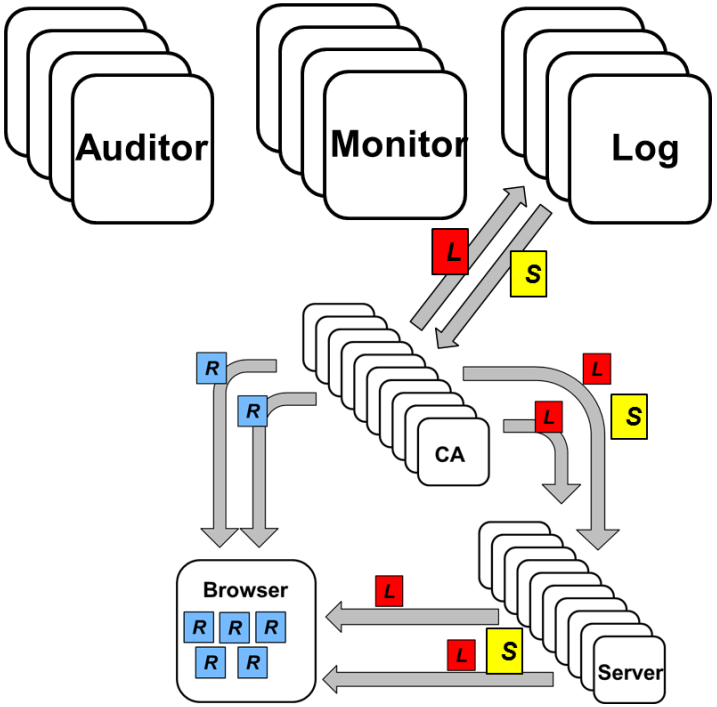

Efficiency and sustainability

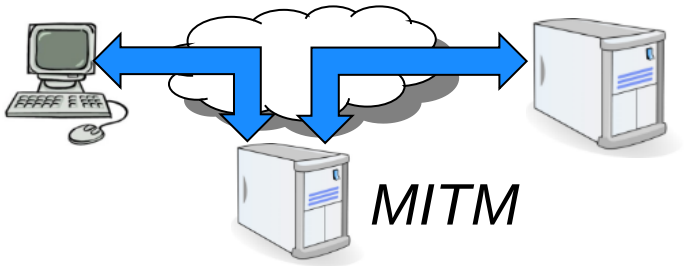


Characterization, analytics, modeling

… HTTPS trust landscape + CT …





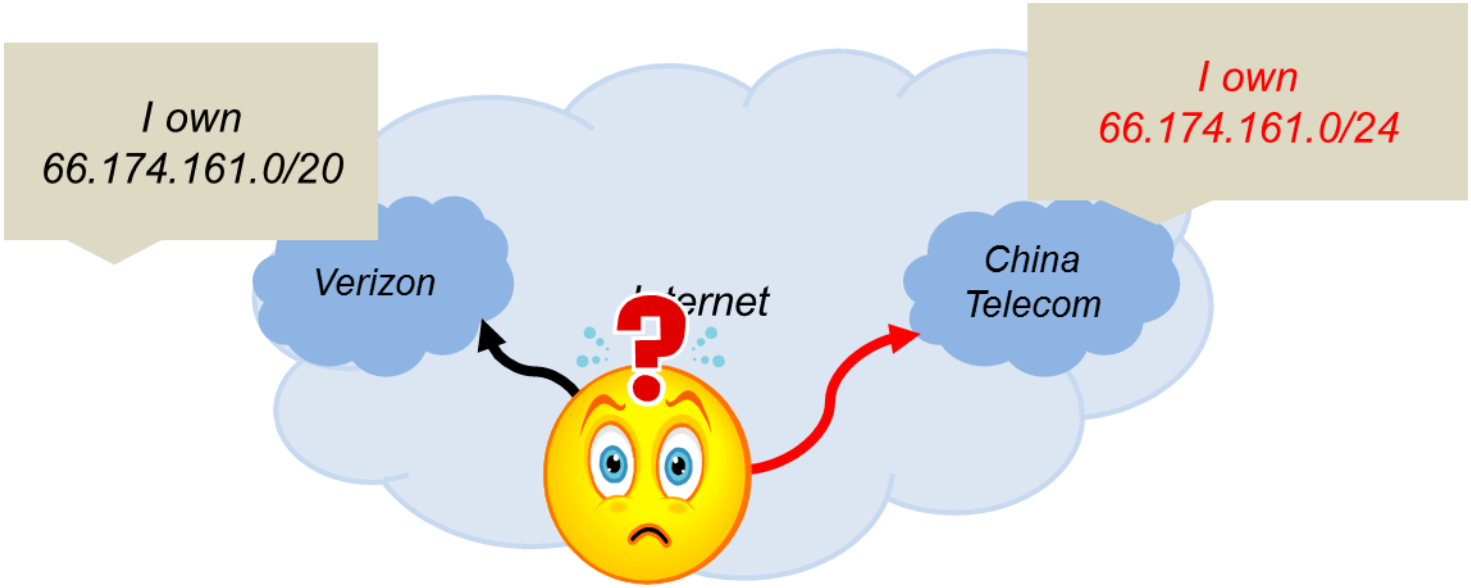


IEEE ComMag 2017

PAM 2018

PAM 2017

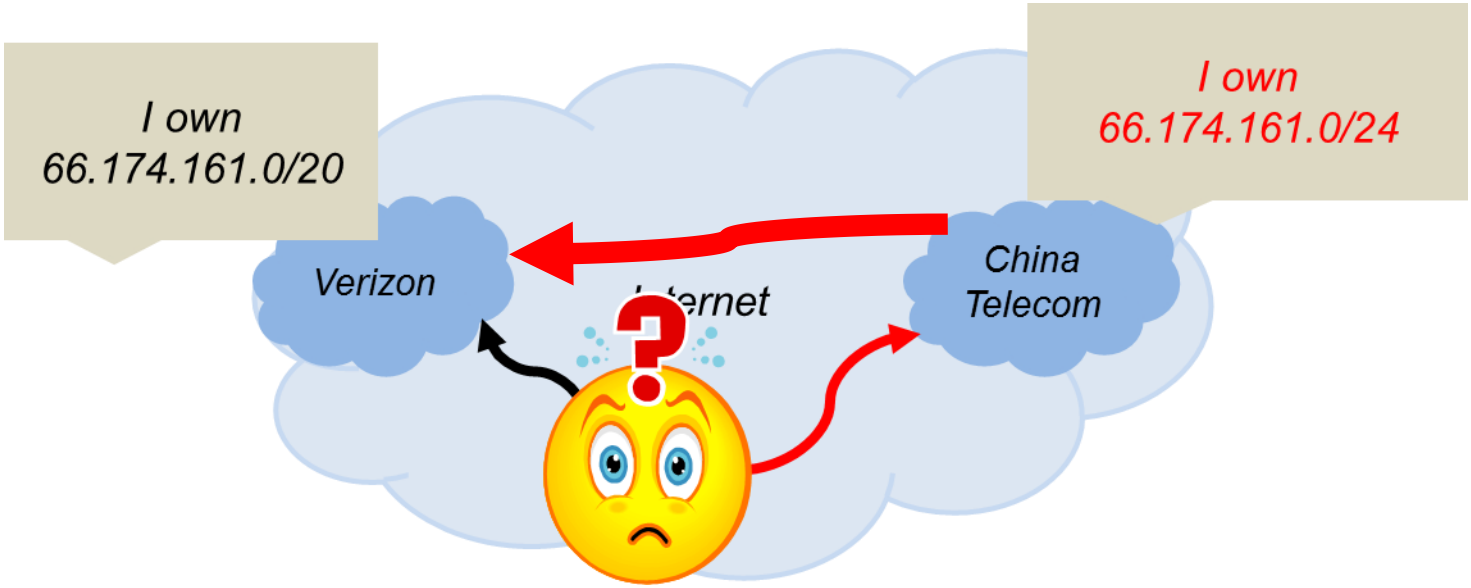
… securing wide-area routing.



IFIP Networking 2016

PAM 2013

… securing wide-area routing.



IFIP Networking 2016

PAM 2013

Research overview

Design, modeling, and performance evaluation of distributed systems and networks

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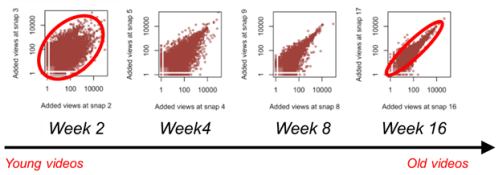
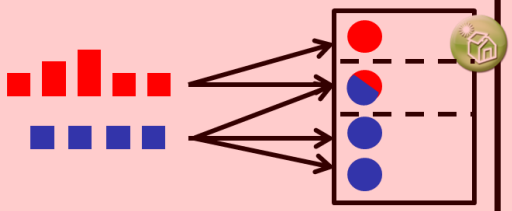
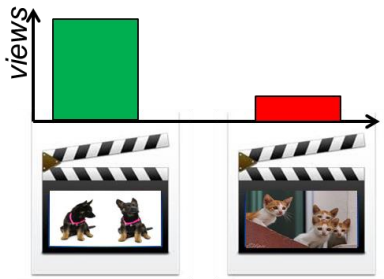


Popularity dynamics

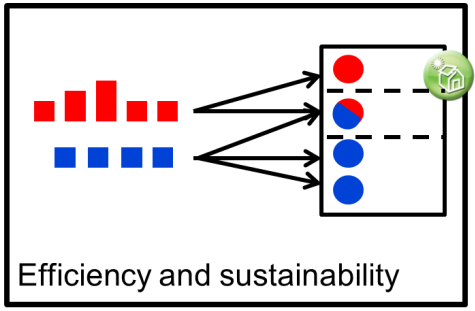
Network security



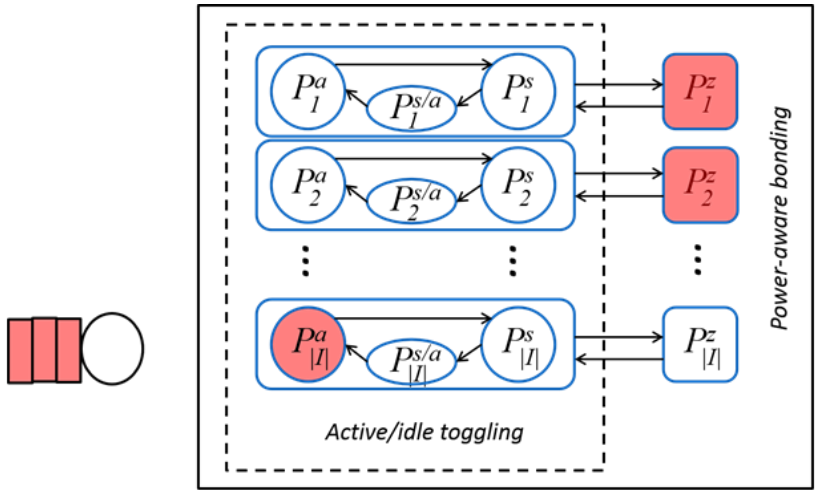
Efficiency and sustainability

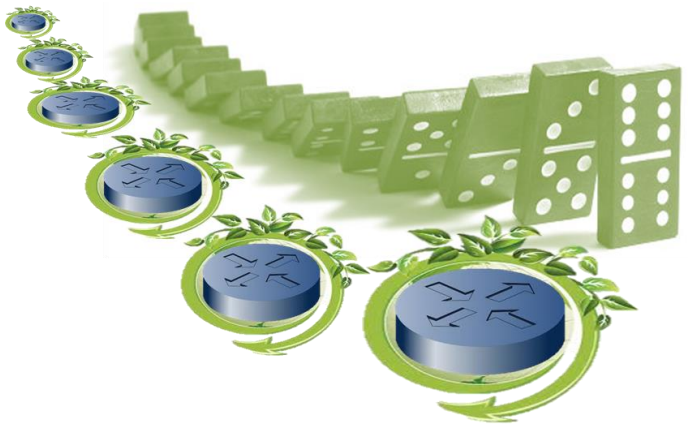


Characterization, analytics, modeling



… energy efficient routers/servers …





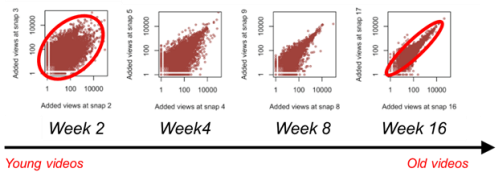
ACM/SPEC ICPE 2011, 2013, 2015, 2016

Research overview

Design, modeling, and performance evaluation of distributed systems and networks

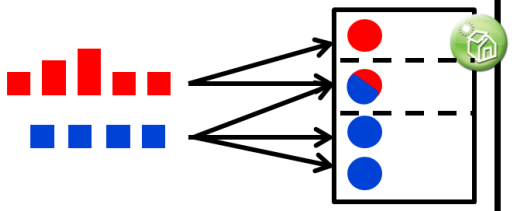

Tomorrow's streaming


Scalable content delivery

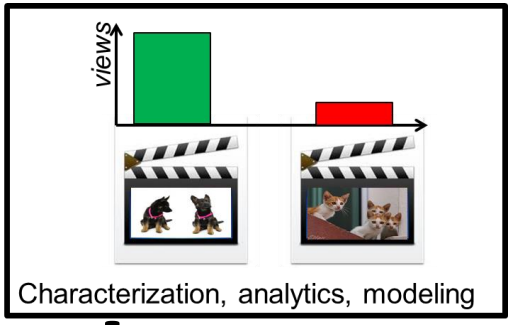


Popularity dynamics

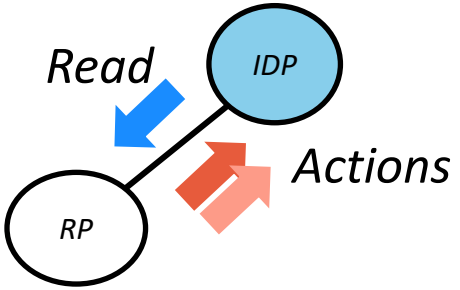
Network security

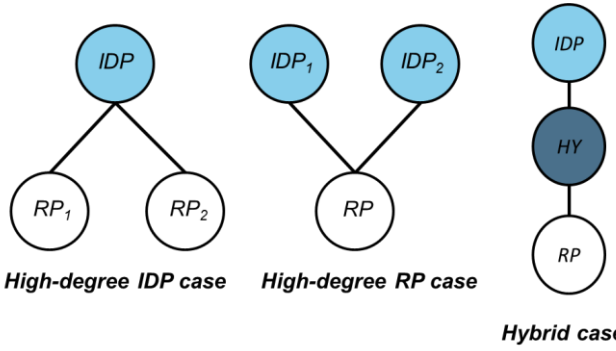

Efficiency and sustainability

Characterization, analytics, modeling

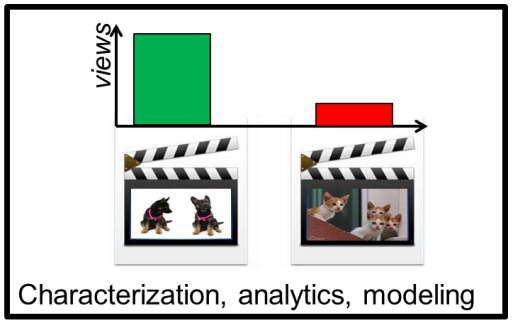


… third-party information leakage …

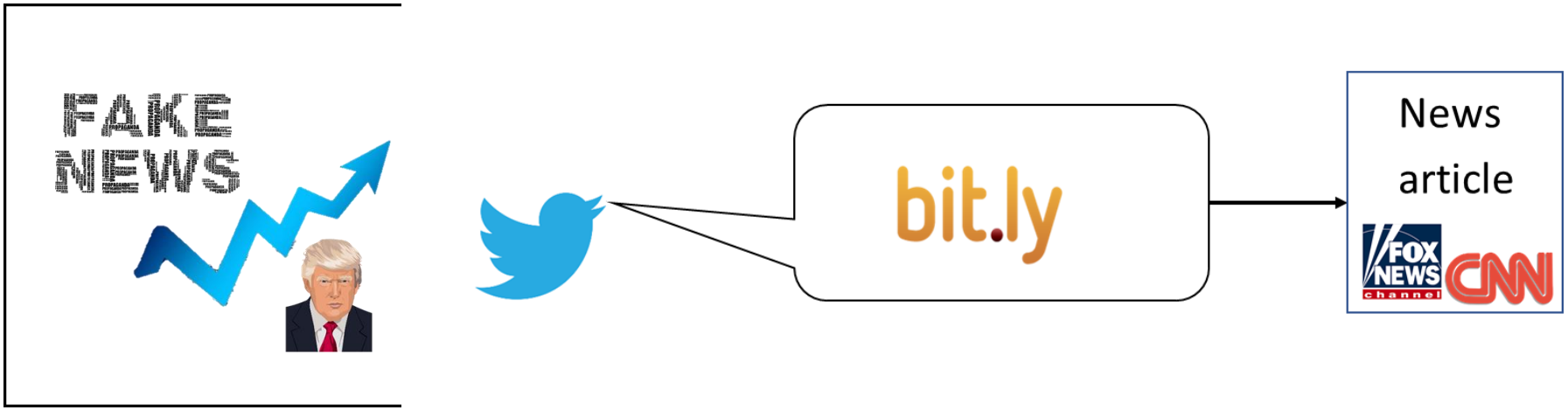


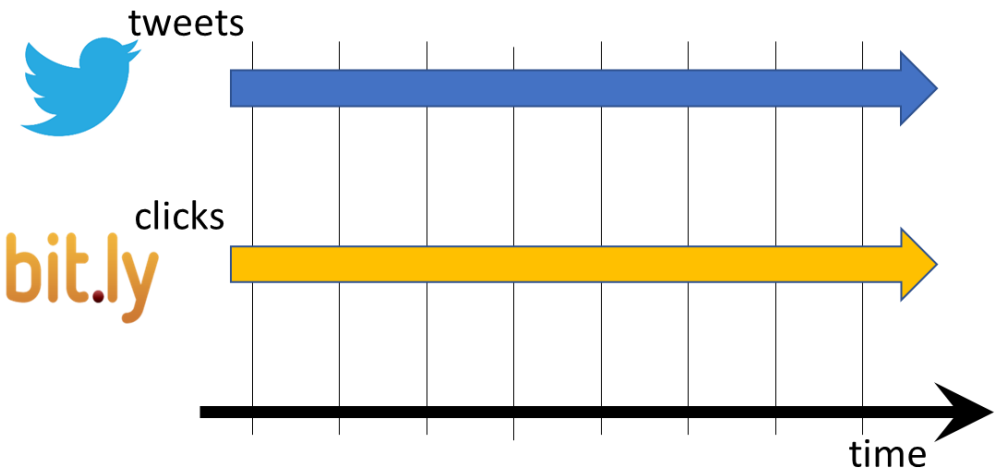


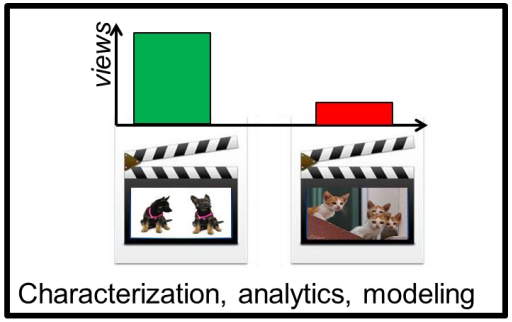
IEEE IC 2016
IFIP SEC 2015
PAM 2014


views
Characterization, analytics, modeling

… fake news …


FAKE
NEWS
bit.ly
News
article
FOX NEWS channel
CNN

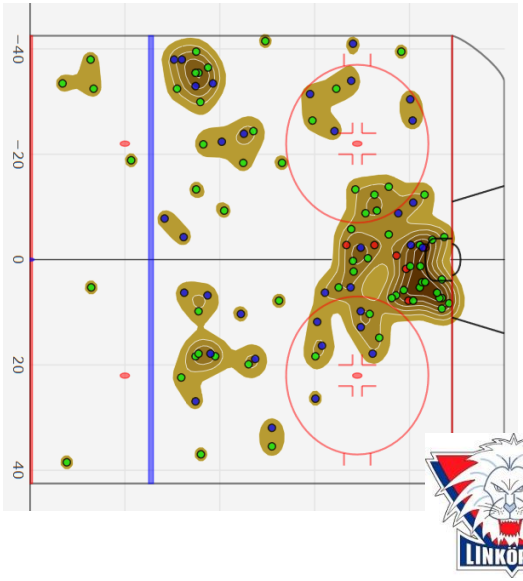

tweets
clicks
bit.ly
time



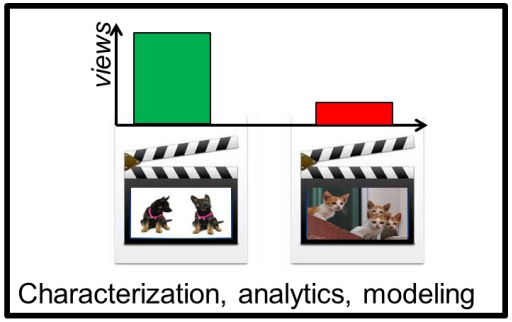
… sports analytics …

Player Valuation in European Football

Player Pairs Valuation in Ice Hockey

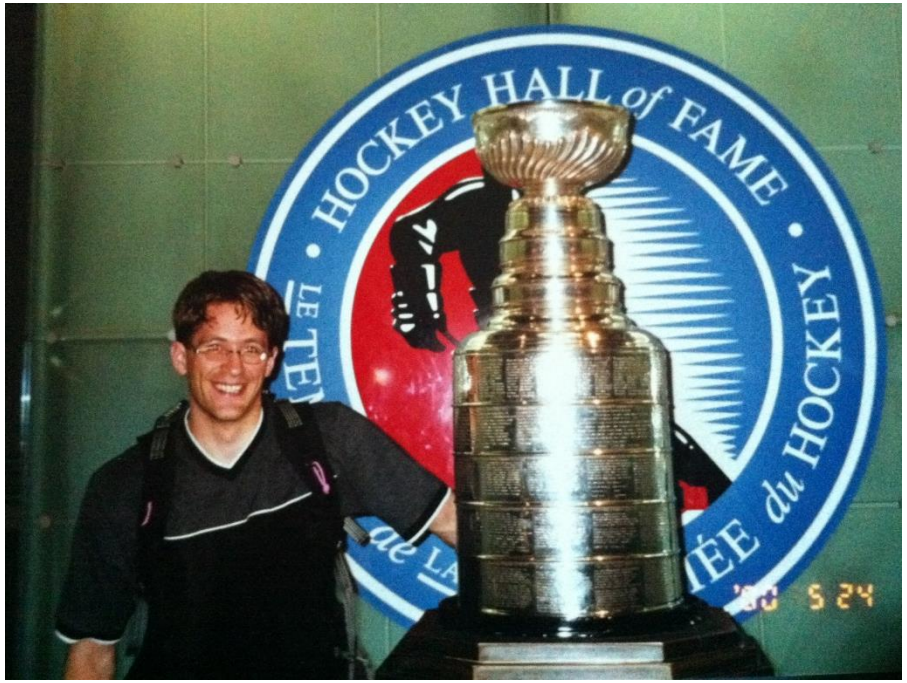


MLSA 2018, MLSA 2019, MathSport 2019

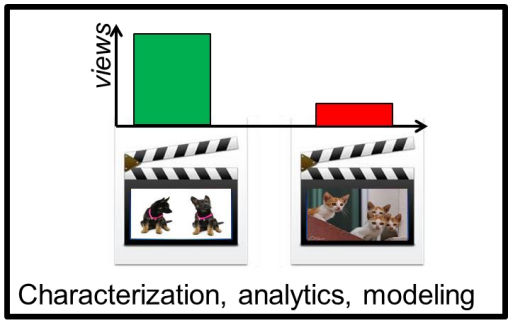


… sports analytics …

… or just another attempt to win the Stanley Cup ??



MLSA 2018, MLSA 2019, MathSport 2019

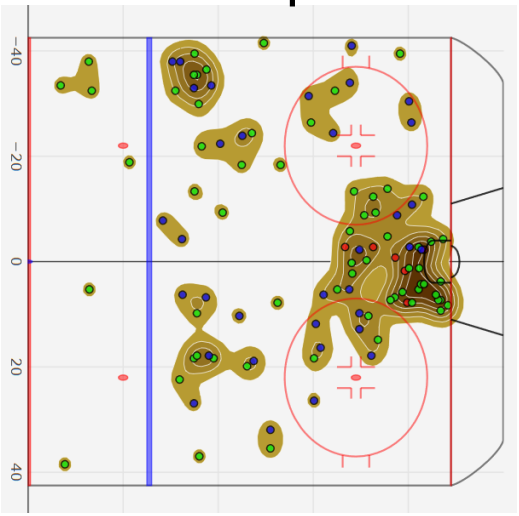


… sports analytics …

1st attempt …

2nd attempt …

3rd attempt …



MLSA 2018, MLSA 2019, MathSport 2019

So perhaps the ultimate goal is to help ensure that I will have an …

So perhaps the ultimate goal is to help ensure that I will have an …

… “interactive” front-row seat …

So perhaps the ultimate goal is to help ensure that I will have an …

... “interactive” front-row seat …

... to watch **my** favorite team win the Stanley Cup …

So perhaps the ultimate goal is to help ensure that I will have an …

... “interactive” front-row seat …

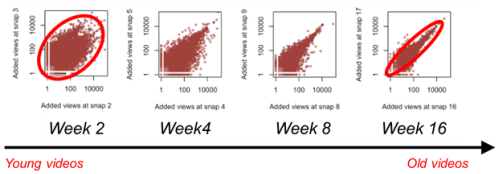
... to watch **my** favorite team win the Stanley Cup …

… securely, from anywhere in the world!

Thanks for listening!

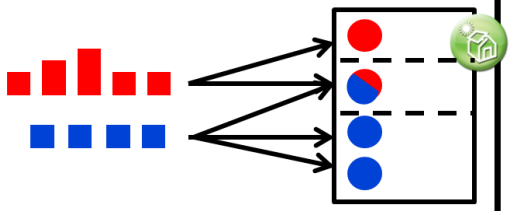

Tomorrow's streaming

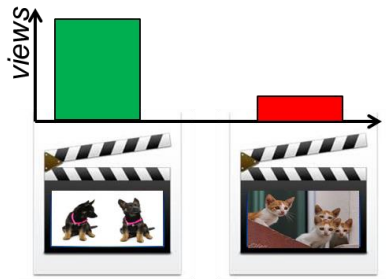

Scalable content delivery



Popularity dynamics

Network security


Efficiency and sustainability



Characterization, analytics, modeling

LINKÖPINGS UNIVERSITET

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Research overview and pubs: www.ida.liu.se/~nikca89/