Smart Caching in Content Centric Networking

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Cooperating groups of the technical faculty:

- Multimedia Communication
- Intelligent Systems and Business Informatics

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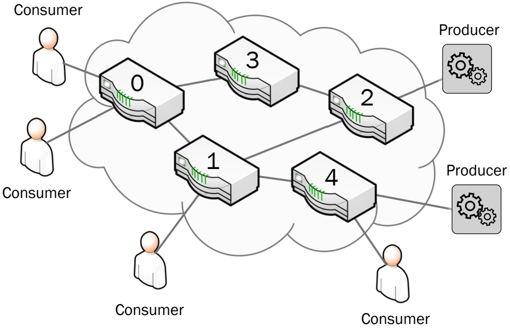
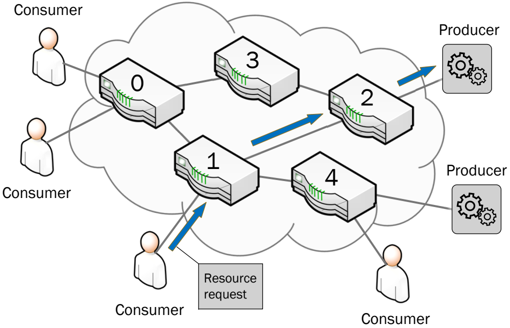
Agenda

Networking Agents



- Resource distribution networks are often host-oriented:
  - multimedia content,
  - power grids, etc.
- Typical resource network comprises:
  - *static* distribution/routing subnet and
  - *dynamic* subnet of resource producers and consumers

Networking Agents



- The basic interaction can be presented as follows:
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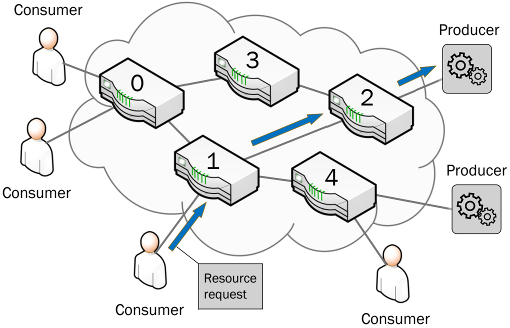

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  - Nodes of the distribution subnet forwards the request to one of the known resource producers

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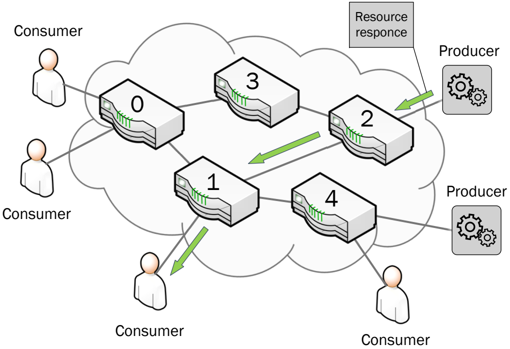
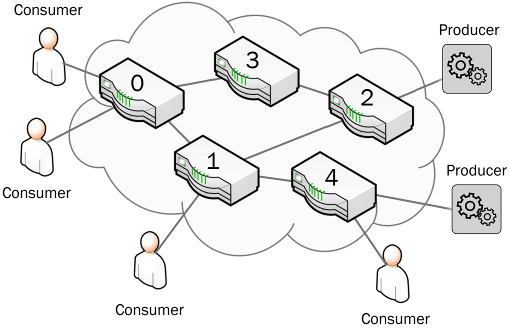
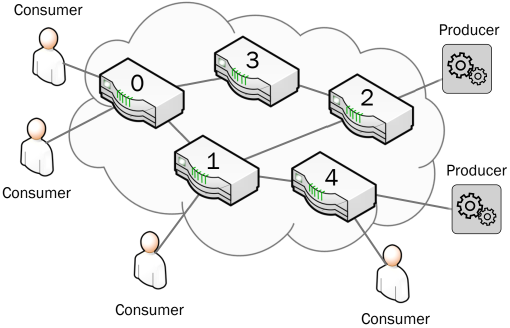


- The basic interaction can be presented as follows:
  - Consumers issue resource requests to the network
  - Nodes of the distribution subnet forwards the request to one of the known resource producers
  - The resource is forwarded back to the consumer

Smart-Networking Agents



- Host-oriented networks have no answer to modern challenges:



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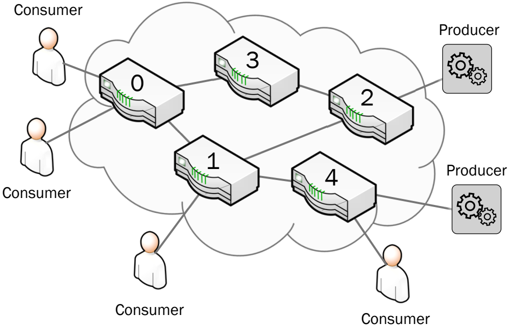

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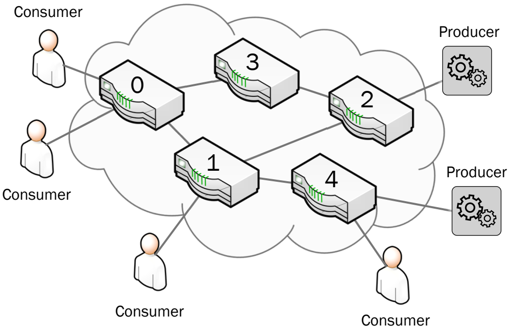
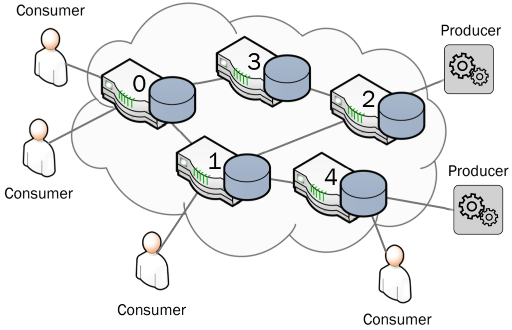


- Host-oriented networks have no answer to modern challenges:
  - Automatic fault detection and self-healing
  - Bi-directional flow of resources
  - Demand-side management of interest requests

Smart-Networking Agents



- Evolution of networks towards intelligent distribution subnets

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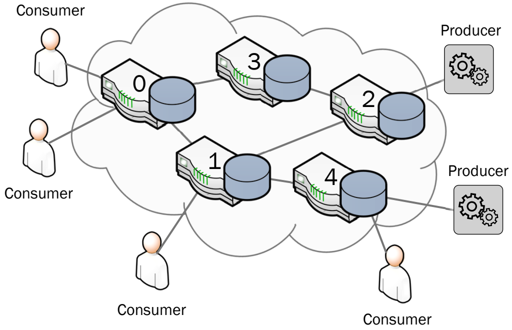
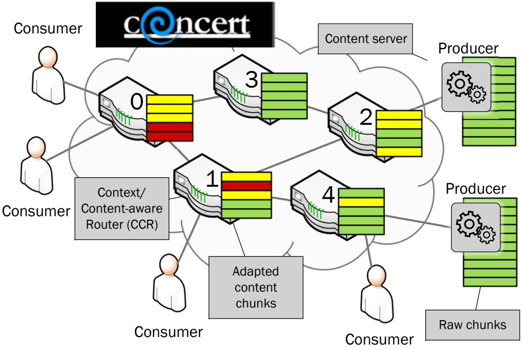


- Evolution of networks towards intelligent distribution subnets
- Current proposals for content-centric networking, smart grids, etc. suggest that nodes of the network can have:
  - a resource storage/production unit
  - a set of strategies for resource acquisition and distribution
  - a decision unit for (online) selection of the strategy

Content-Centric Networking



- The content in the network is addressed by "name" – physical location is irrelevant
- CCR must be able to route interest packages, cache and adapt media chunks in highly dynamic conditions

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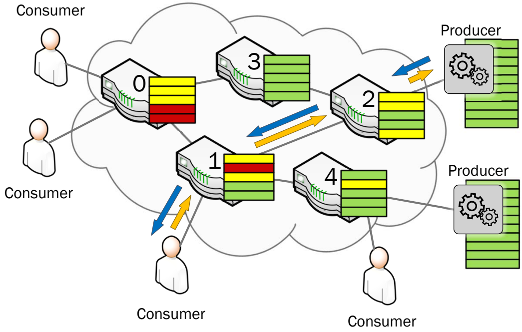
Content-Centric Networking



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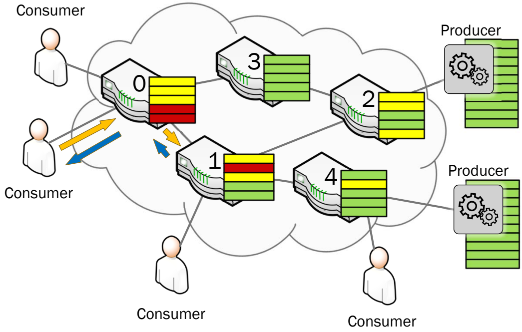

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Caching Scenarios in CCNs

- Content consumption in CCNs may vary depending on different factors
- *Current daytime* has high correlation with numbers of active users and their behavioral patterns
- Some sample scenarios are:
  - Morning: the number of active users is low and they are interested in different media
  - Evening: in the evening a lot of users are watching a small amount of popular series
- Possible caching strategies for the scenarios above:
  - Random: replaces a *random chunk* in the cache with the current chunk received by the networking unit
  - LFU: the received chunk replaces the *Least Frequently Used chunk* of the cache

There is no “silver-bullet”!

- Different caching strategies, like Random, LFU or Traffic-aware Flow Offloading (TFO), work best when applied in appropriate settings

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Automating Administration of CCNs

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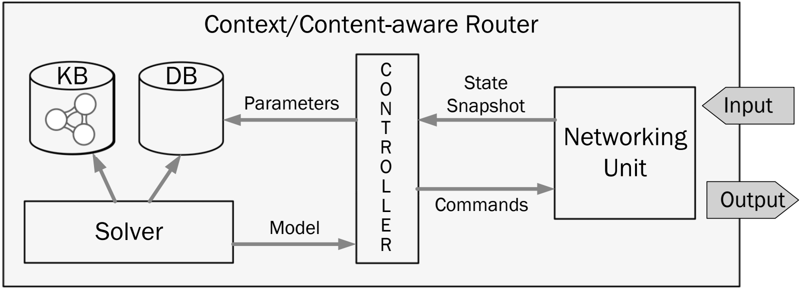
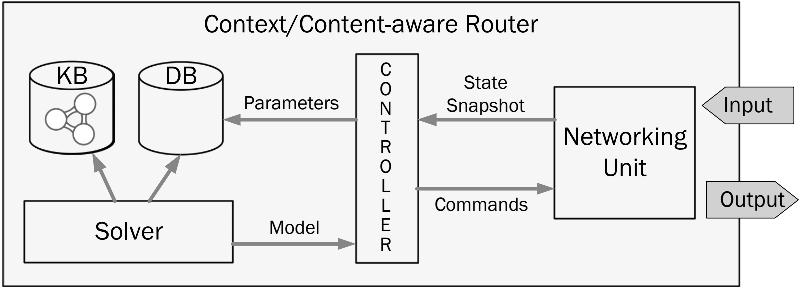
- Administrators can change these strategies depending on their understanding of the current situation in the network
- Our research aims at automation of administrative tasks, like selection of a caching strategy
- CCRs must be able to react to changing environment

Extended CCR Architecture



- Legacy components of a CCR:
  - Networking unit: implements network interfaces
  - Controller: manages content adaptation, routing and caching

Extended CCR Architecture



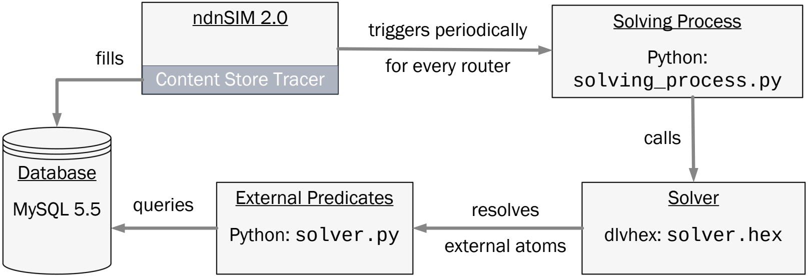
- Legacy components of a CCR:
  - Networking unit: implements network interfaces
  - Controller: manages content adaptation, routing and caching
- Extended architecture:
  - Knowledge-based system: selection of a controller's decision making strategy
  - Human-readable knowledge representation language is necessary for administrative actions

Modeling Cache Selection with LARS

- Automation of administrative tasks requires a CCR to:
  - Make decisions over a stream of events
  - Reason about temporal properties of the events
- LARS allows to model and solve the strategy selection problem
- Example: use random strategy if not so many users are active and their interests are different

$$
\begin{aligned}
@_T alpha\_low &\leftarrow \boxplus^{[s,e]} @_T alpha(V), V \geq 0.5, V \leq 1. \\
@_T load\_middle &\leftarrow \boxplus^{[s,e]} @_T load(V), V \geq 25, V \leq 55. \\
@_T in\_use(random) &\leftarrow \boxplus^{[s,e]} @_T in\_use(V), V = random. \\
cnd(random) &\leftarrow \boxplus^{[s,e]} (\Box alpha\_low \land \Box load\_middle \\
&\qquad \land \neg \Diamond in\_use(random)).
\end{aligned}
$$

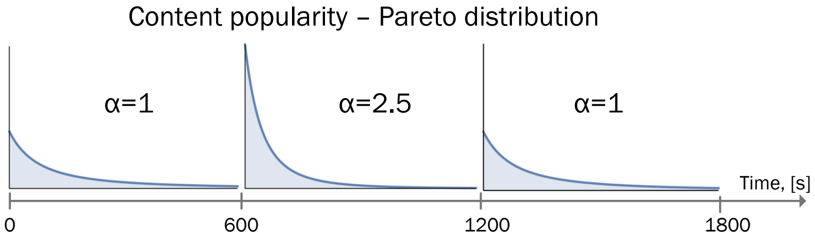
Implementing the Framework



- `ndnSIM` is a general network simulator
- `solver.hex` implements the LARS framework
- `solver.py` comprises implementation of external predicates, for instance:
  - *alpha*/1: returns the α value of the Pareto distribution – measure of the content popularity
  - *load*/1: the number of packets processed by the router

Experiment Setup I

- In the experiment we simulated a scenario in which the popularity of some content is changing
- In the first and third intervals of the time line the users are interested in different media
- The second interval is characterized by a high popularity of a small number of available videos

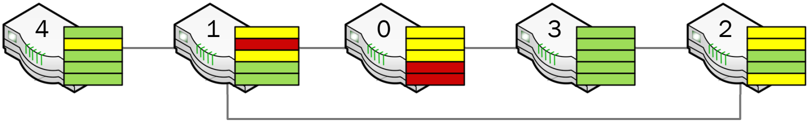


Experiment Setup II

- Parameters of the simulator:

Number of Routers	5	Number of Users	200
Number of Videos	20	Video Duration [s]	60
Chunks per second	30	Cache Size [#Chunks]	125
Cached Video (Router) [s]	4	Cached Video (Network) [s]	20
Solver Timeout [s]	30	Simulation Time [s]	1800

Network topology

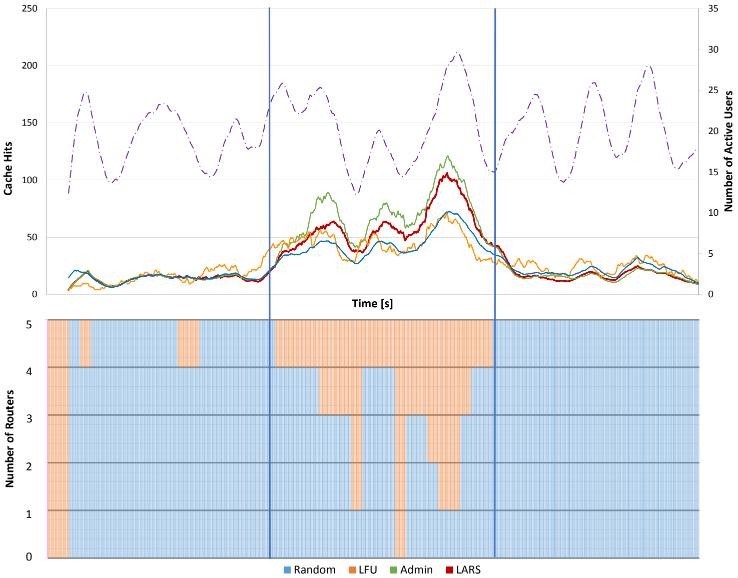


Experiment Setup III

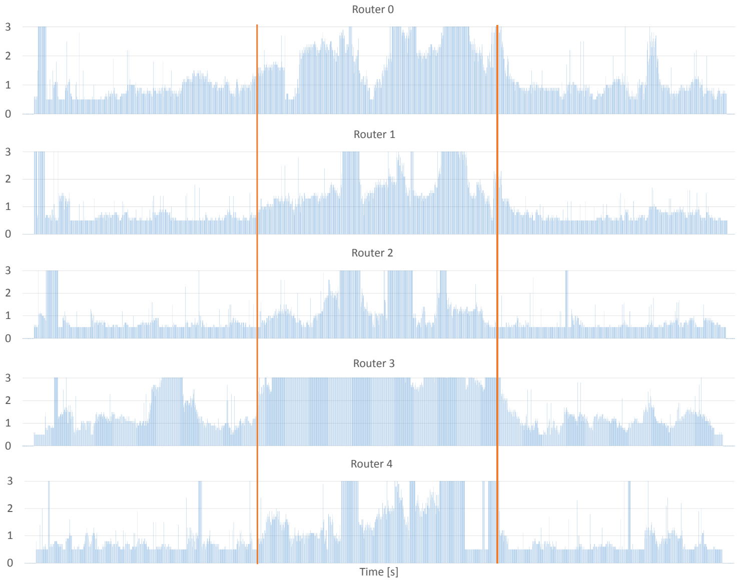
Evaluated variants of CCR decision making:

- *LARS* – decisions about the caching strategy used by a controller are taken by LARS
- *Admin* – we apply Random in first and third intervals and LFU in the second. The strategy is switched exactly at a time point when a simulator changes the α value
- *Random* – the Random strategy is applied by each CCR at all times
- *LFU* – all CCRs use the LFU strategy at all times

Preliminary Results



Measured α-values



Conclusions & Future Work

- Experimental results show that smart CCRs react well on changing environment
- LARS-based strategy could outperform single strategies

# hits	Strategy			
	LARS	Admin	LRU	Random
Average	30,14	33,64	23,28	26,59
Total	54251	60559	41901	47858

- Better encoding is required to ignore outliers, e.g. sudden peaks of user activity
- Introduce communication between CCRs – group decision-making for better resource allocation
- Develop diagnosis methods for automated fault-detection and self-healing, e.g. when a router is taken offline