

# Media Streams Planning Problem in CoUniverse

Miloš Liška

`xliska@fi.muni.cz`

Faculty of Informatics, Masaryk University, Czech Republic



*MEMICS2009*

Znojmo, 2009–11–14



# Talk Overview

- Motivation
- CoUniverse Overview
- Media Streams Planning Problem in CoUniverse
- Proof of Concept Implementation Evaluation
- Conclusions and Future Work



# Motivation

- Advanced collaborative environments and distributed applications
  - Using high-quality, high-definition media streams to build collaborative environment
    - bandwidth demands comparable to network link speeds (10 GbE) requires careful planing and configuration of infrastructure
    - lacks adaptivity to changing networking conditions
  - Large numbers of components needed to build the environment
    - each one of them needs to be configured
    - hard to orchestrate them manually to build the desired environment
    - virtually impossible to cope with network events manually



## CoUniverse Overview

- Middleware aimed on self-organization and orchestration of applications to build ad-hoc environments for real-time data transmissions on top of physical networking infrastructure
- Support for legacy applications producing streams with bitrate comparable to capacity of the network links
- User-empowered approach where possible
  - end-to-end view of networking topology
- Self-organization based on careful planning of media streams transmissions over network links
- Continuous adaptation to changing networking infrastructure
- Capable of interfacing with optical networks provisioning middleware
  - DCN – dynamic on-demand provisioning of user-requested network circuits over multiple networks (administrative domains)



# CoUniverse Building Blocks

- Components
  - Network nodes running CoUniverse peers, holds the local configuration (network interfaces, applications)
  - Media applications organized into application groups
  - Application Group Controller (AGC)
    - updates the network topology
    - plans the transmissions of streams over the network infrastructure
    - orchestrates the applications
  - Network control
  - Monitoring
  - Visualisation



# Modeling CoUniverse orchestrated applications

- nodes  $v \in V$  with configured media applications
  - producers  $p \in P$  producing/sending media streams
  - consumers  $c \in C$  consuming/receiving media streams
  - distributors  $m \in M$  distributing media streams over several network links to the consumers
- network link  $e \in E$  with its properties
  - beginning node  $begin(e)$
  - ending node  $end(e)$
  - capacity  $cap(e)$
  - latency  $lat(e)$



# Modeling CoUniverse orchestrated applications

- Streams  $s \in S$  media stream transmitted between two media applications
  - $bw(s)$  is a bitrate of the stream
  - for each stream  $s \in S$  we can tell its source media application  $begin(s) \in P \cup M$
  - for each stream  $s \in S$  we can tell its target media application  $end(s) \in M \cup S$
- Simplified model is presented
  - let us assume that we can obtain  $consumers(p)$  for each  $p \in P$ ,  $consumers(p)$  is a set of all consumers that request to receive the media stream produced by particular producer  $p$
  - we also omit the ability of media distributors to transcode the media streams



# Media Streams Planning Problem in CoUniverse

- Variant of the path placement problem
- The problem of many applications in networks is to decide which path to use for satisfying certain demands under constraints given by the network
- A demand acceptance problem, Link-based planning model (Simonis, 2006)
  - For each demand (transmission of stream  $s \in S$ ) we have one decision variable per link  $e \in E$  which states if the link is used or not
  - Stream link  $s/(e, s) = \begin{cases} 1 & \text{if } s \text{ is transmitted over } e \\ 0 & \text{otherwise} \end{cases}$
  - Goal: find all stream link values considering given constraints and optimization criteria



# Media Streams Planning Problem in CoUniverse

## Constraints Based on Data Distribution and Network Links Properties

- Each producer with only one consumer must send the stream through at least one link and at most  $\|M\| + 1$  links

$$\forall p \in P, (\|consumers(p) = 1\|) : 1 \leq \sum_{e \in E} sl(e, s) \leq (\|M\| + 1)$$

- Each producer with more than one consumer must send the stream through at least  $\|consumers(p)\| + 1$  links and at most  $\|consumers(p)\| + \|M\|$  links

$$\forall p \in P, (\|consumers(p) > 1\|) : (\|consumers(p)\| + 1) \leq \sum_{e \in E} sl(e, s) \leq (\|consumers(p)\| + \|M\|)$$

- The bandwidth requested by the streams transmissions must not exceed the capacity of the network links

$$\forall e \in E \sum_{s \in S} bw(s) \cdot sl(e, s) \leq cap(e)$$



# Media Streams Planning Problem in CoUniverse

## Constraints Based on Producers and Consumers Properties

- Each producer  $p$  is producing/sending the stream  $s$  using exactly one network link  $e$

$$\forall p \in P : \sum_{e \in E, p = \text{begin}(s)} \|sl(e, s) = 1\| = 1$$

- Each consumer  $c$  is receiving/consuming the stream  $s$  using exactly one network link  $e$

$$\forall c \in C : \sum_{e \in E, c = \text{end}(s)} \|sl(e, s) = 1\| = 1$$

- There is no direct stream link between producer and its consumers if there is more than one consumer requesting stream from this producer

$$\forall p \in P, \forall c \in \text{consumers}(p) : ((\|\text{consumers}(p)\| > 1) \wedge (p = \text{begin}(s)) \wedge (c = \text{end}(s))) : sl(e, s) = 0$$



# Media Streams Planning Problem in CoUniverse

## Constraints Based on Media Distributors Properties

- Media distributor is used to distribute streams coming just from a single producer (or media distributor)

$$\forall m \in M : \sum_{e \in E, m = \text{end}(s)} \|sl(e, s) = 1\| \leq 1$$

- Media distributor is capable to distribute the streams to more consumers (or media distributors)

$$\forall s \in S, \forall m \in M : \sum_{e \in E, m = \text{end}(s)} \|sl(e, s) = 1\| = 0 \implies \sum_{e \in E, m = \text{begin}(s)} \|sl(e, s) = 1\| = 0$$

$$\sum_{e \in E, m = \text{end}(s)} \|sl(e, s) = 1\| = 1 \implies \sum_{e \in E, m = \text{begin}(s)} \|sl(e, s) = 1\| \geq 1$$



# Media Streams Planning Problem in CoUniverse

## Optimization Criteria

- Global latency minimization

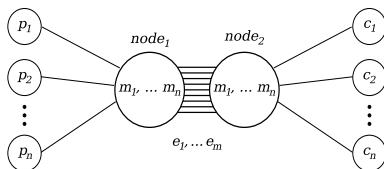
$$\text{minimize } \sum_{e \in E} \sum_{s \in S} lat(e) \cdot sl(e, s)$$

- Global stream quality maximization
- Path latency balancing
  - videoconferences, latency between all producers and consumers is balanced



# Media Streams Planning Problem Complexity

- Linear reduction of 1-0 Multiple Knapsack Problem



$$\begin{aligned}
 &\text{maximize} && \sum_{i=1}^m \sum_{j=1}^n (LAT - lat_i) x_{ij} \\
 &\text{subject to} && \sum_{j=1}^n max\_b_j x_{ij} \leq CAP_i, && \text{for all } 1 \leq i \leq m \\
 &&& \sum_{i=1}^m x_{ij} \leq 1, && \text{for all } 1 \leq j \leq n \\
 &&& x_{ij} \in \{0, 1\}, && \text{for all } 1 \leq j \leq n \text{ and all } 1 \leq i \leq m \\
 &&& \text{where } x_{ij} \text{ corresponds with a stream link } s(i, j)
 \end{aligned}$$

- MSPP belongs to the class of  $NP$ -complete problems



# Simplifying the MSPP

- Reduction of the MSPP state space size (number of stream links)
- Elimination of network links
  - capacity based elimination
  - loop links elimination
  - intra site network links elimination
  - consumers and producers based links elimination



## Proof of Concept Evaluation

- Based on CoUniverse prototype using Choco solver 1.2.5 library to implement the constraint based programming solving the media streams planning problem

Table: CoUniverse scheduling evaluation (all feasible solutions)

Distribution scheme	Sites	Nodes	Network links	Media applications	Media distributors	Planning time [s]
m:n	2	6	60	6	2	0,178
m:n	3	12	264	12	3	0,510
m:n	4	20	760	20	4	1970,540
1:n	2	5	40	5	1	0,181
1:n	7	20	760	20	1	1,110
1:n	8	24	1104	24	2	8,914
1:n	10	30	1740	30	2	37,299
1:1	2	4	24	4	0	0,187
1:1	5	10	180	10	0	0,333
1:1	11	22	924	22	0	2,009
1:1	17	34	2244	34	0	6,160
1:1	23	46	4140	46	0	21,661



## Summary and Conclusions

- Working open-source prototype implementation of CoUniverse aimed on high-quality ad-hoc collaborative environments
- Source code available to download
  - <https://www.sitola.cz/CoUniverse/>
- Several successful demonstrations of CoUniverse features
  - GLIF 2007
  - SC'07
  - I2 Winter Joint Techs Meeting 2009
  - I2 2009 Spring Member Meeting



# Future Work

- Media stream planning improvements
  - media streams scheduling utilizing improved monitoring
  - not relying on constraint scheduler to find the plan for media applications
    - find and use a heuristic approach to find a mapping of media streams to particular network links
    - use the constraint scheduler to verify such a plan
  - more sophisticated scheduling
    - media streams transcoding, point-to-multipoint media streams
  - less sophisticated scheduling
    - applications using low-bandwidth streams



Thank you for your attention!

*Q?/A!*

`xliska@fi.muni.cz`

