

# DIONASYS

Declarative and Interoperable Overlay Networks,  
Applications to Systems of Systems



## DIONASYS project overview year 3

chist-era meeting

April 2018

Paris

# Introduction

- Declarative and Interoperable Overlay Networks, and Applications to Systems of Systems
- Call 2013 – topic Heterogeneous Distributed Computing
- January 2015 – December 2018
  - ▶ Initially until December 2017
  - ▶ But extended for one year (until December 2018)
- Changes in consortium
  - ▶ Replacement of Université de Neuchâtel (CH) by UCLouvain (BE)
    - Coordinator changed institution
  - ▶ Split of LaBRI tasks between LaBRI and University of Rennes
    - Co-PI changed institution

## ■ Proliferation of heterogeneous and isolated systems

- ▶ Many forms of Cloud systems deployment
- ▶ Wireless and sensor networks
- ▶ Internet of Things
- ▶ Complex networks

## ■ Composition in systems-of-systems leading to advanced services

- ▶ Geo-distributed Cloud systems
- ▶ IoT-Cloud and smart environments
- ▶ Edge and fog computing

## ■ Programming complex, heterogeneous large-scale systems

- ▶ Requires thinking “global”
  - What are the services, the guarantees, the structure
- ▶ But to act “local”
  - Implementing complex interactions at the level of individual nodes

## ■ Problems

Maintainability over time

Adaptation and evolution of functionalities and performance

Interoperability among systems

Composition of existing and future systems

➤ Abstraction mismatch

# DIONASYS objectives

- Raise the level of abstraction for specifying and operating complex systems and system of systems, based on overlays
- Think global, *act* global
  - ▶ Declare the function and structure of the system ...
  - ▶ Including functional and non-functional properties
- Leverage generative programming for overlay networks with gossip-based self-organization and software-defined networks
  - ▶ ... and let DIONASYS generate, augment, evolve, and bridge the corresponding implementation

# Target and previous contributions

- Conceptual framework
  - ▶ Principled systems of systems composition
  - ▶ *Holons framework* [2014]
- Declarative approaches for overlay structures and composition
- Self-organization using gossip-based overlay construction
  - ▶ *Libdio library of self-organizing structures* [2015]
- Adaptation and interoperability
- Integration of programmable networking support and overlay management
  - ▶ Multi-site testbed based on open-stack + OpenFlow

# Contributions in year 3

## Overlay adaptation for wireless systems and adhoc networks

- ▶ Emergent overlays

*Collaboration UCL/UniNE, LaBRI, & Lancaster*

- ▶ Partition detection and routing adaptation

*Collaboration UCL/UniNE, U. Rennes*

## Overlay composition

- ▶ Declarative systems-of-systems construction

*Collaboration LaBRI, U. Rennes*

## Network adaptation

- ▶ Adaptive routing for multi-site edge clouds

*Collaboration UCL/UniNE, TUCN*

- ▶ Intent-driven routing

*Lancaster*

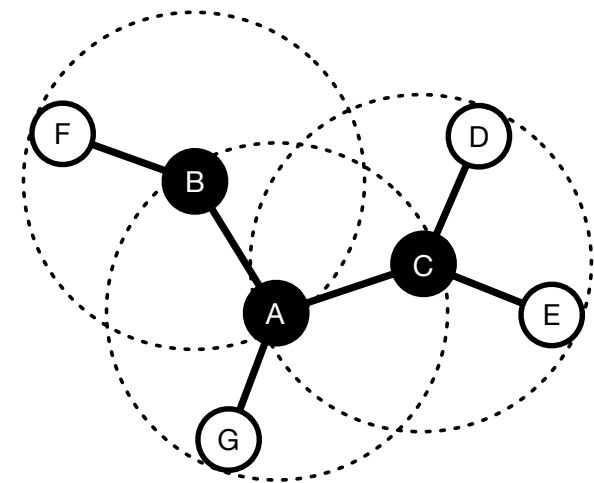
## Broadcast in mobile ad-hoc networks

- ▶ Collisions, energy constraints, heterogeneity
- ▶ Reactive vs. multiple variants of overlay-based approaches
- ▶ Not one size fits all
  - Depending primarily on density and mobility [ICDCS 17]

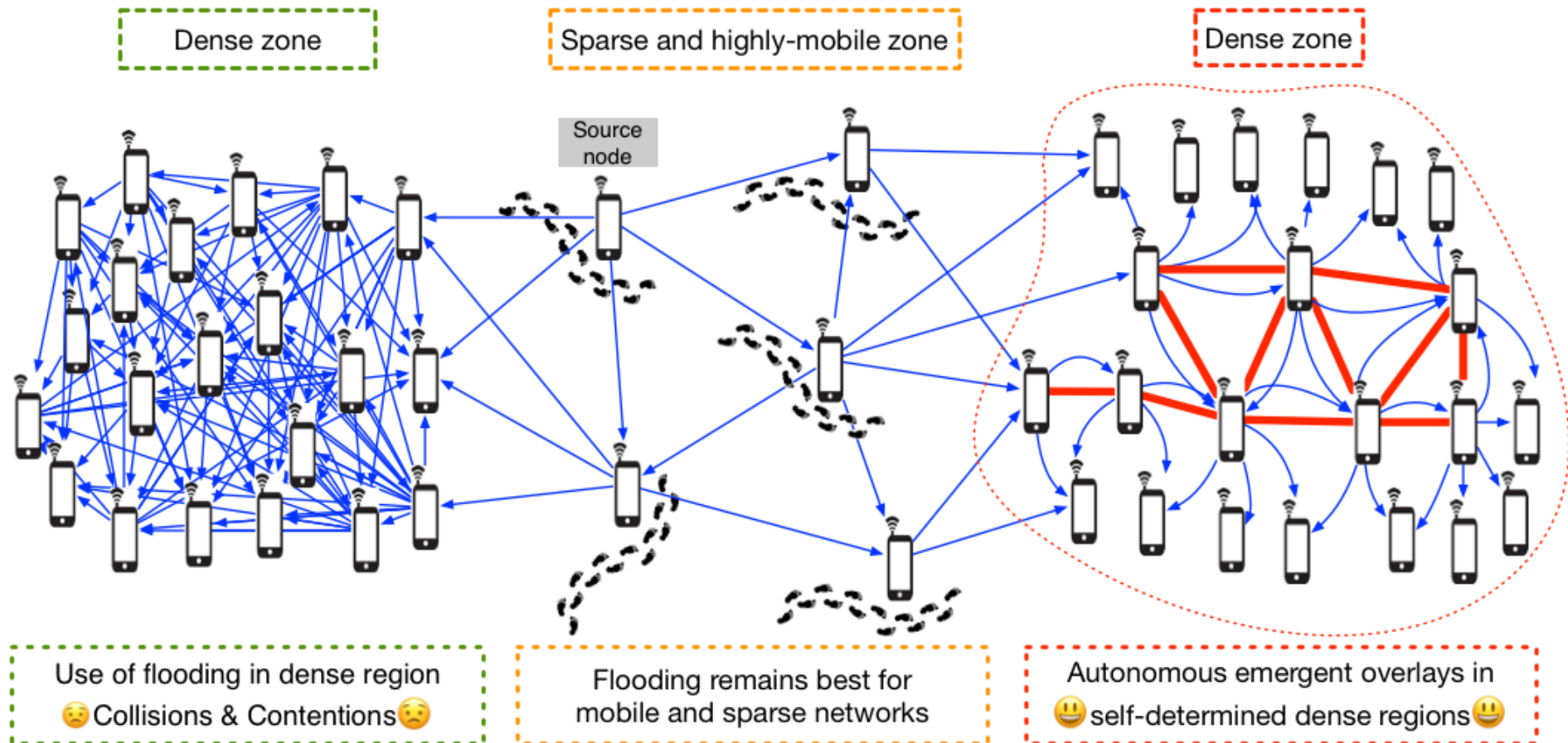
## Emergent overlays

- ▶ Observation of deployment conditions
- ▶ Autonomous shift between protocols
- ▶ Safety guarantees for dissemination

## Under submission

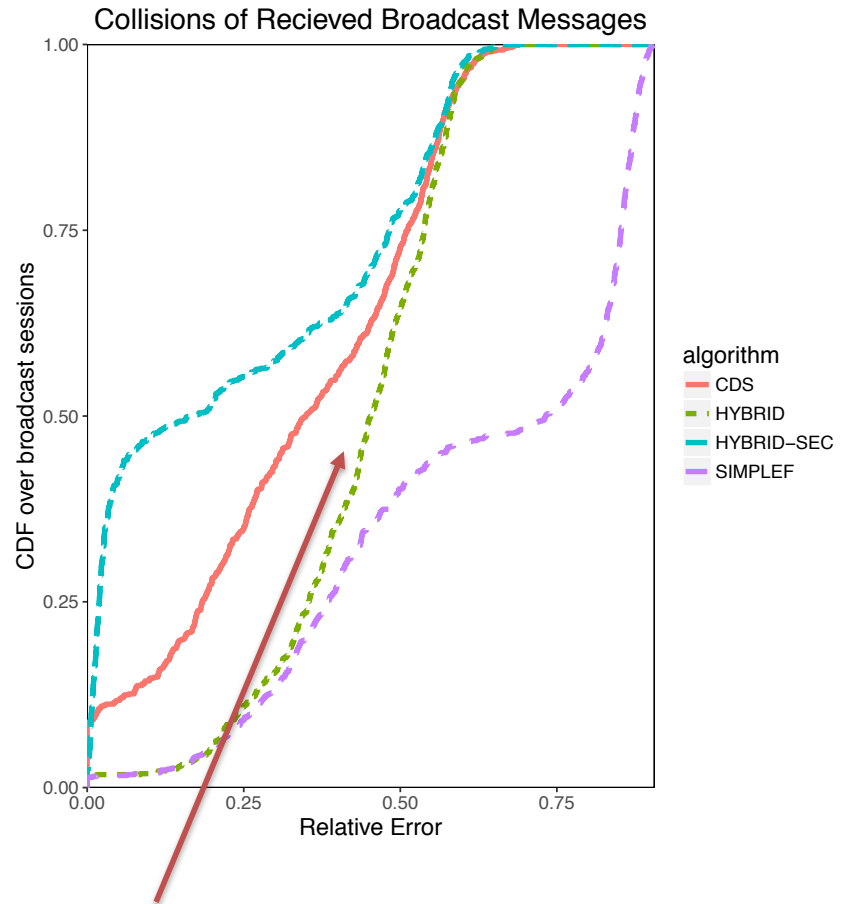
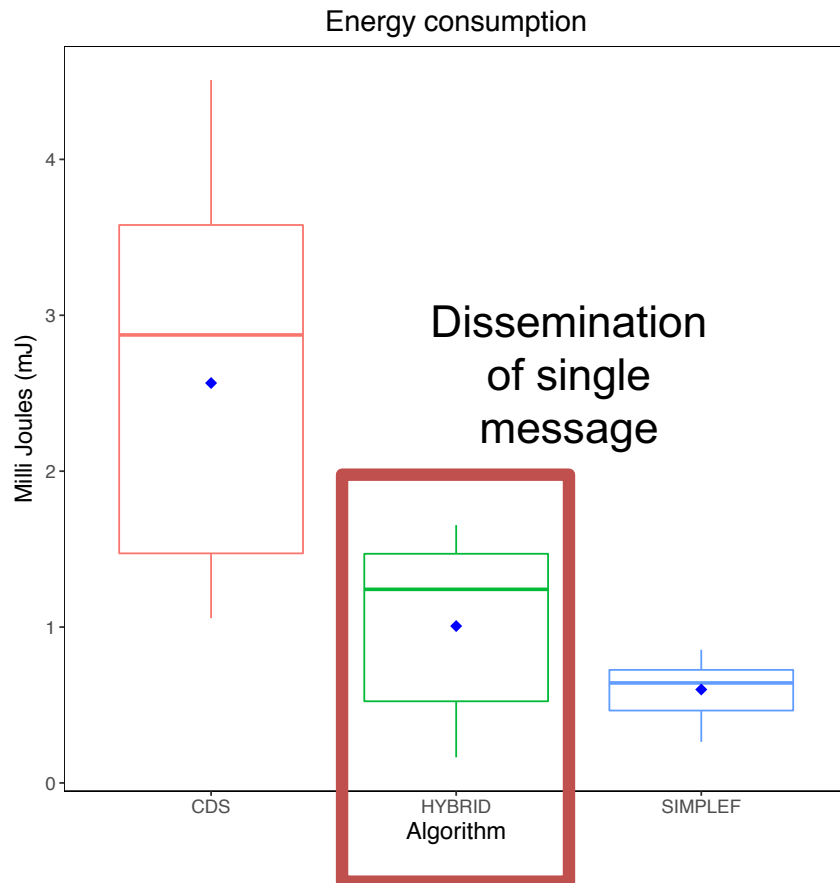


# Emergent overlays



# Results

## Node mobility, two zones: one dense/static, one sparse/dynamic



Less collisions means better coverage (less retries)  
Energy consumption reduced by using overlay only where necessary

# Partition detection and repair

## ■ Application of principle of opportunistic composition

- ▶ Holons [ARM 2016], previous contribution of project
- ▶ Dynamic bridging of heterogeneous systems

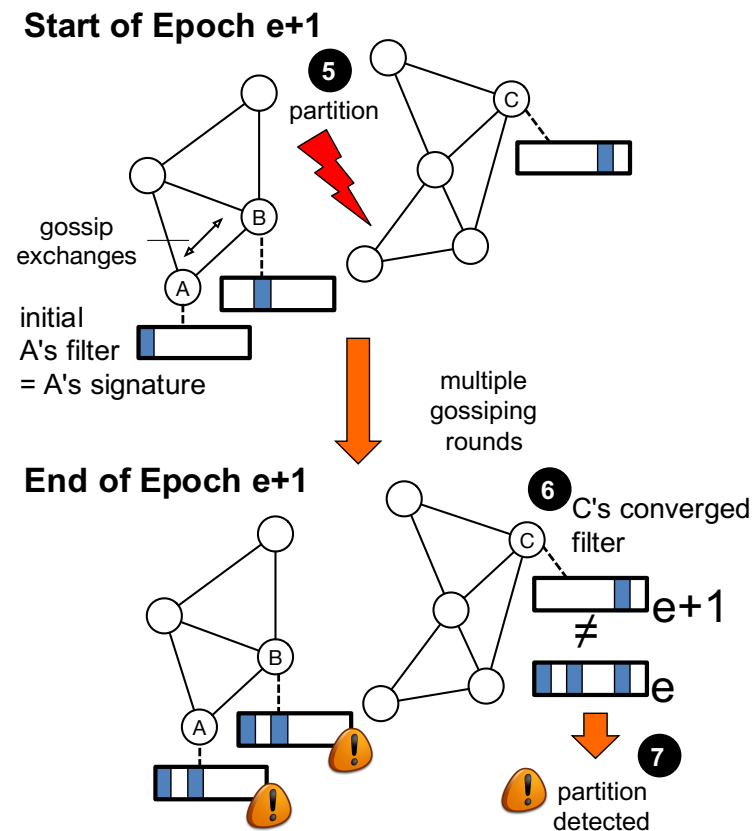
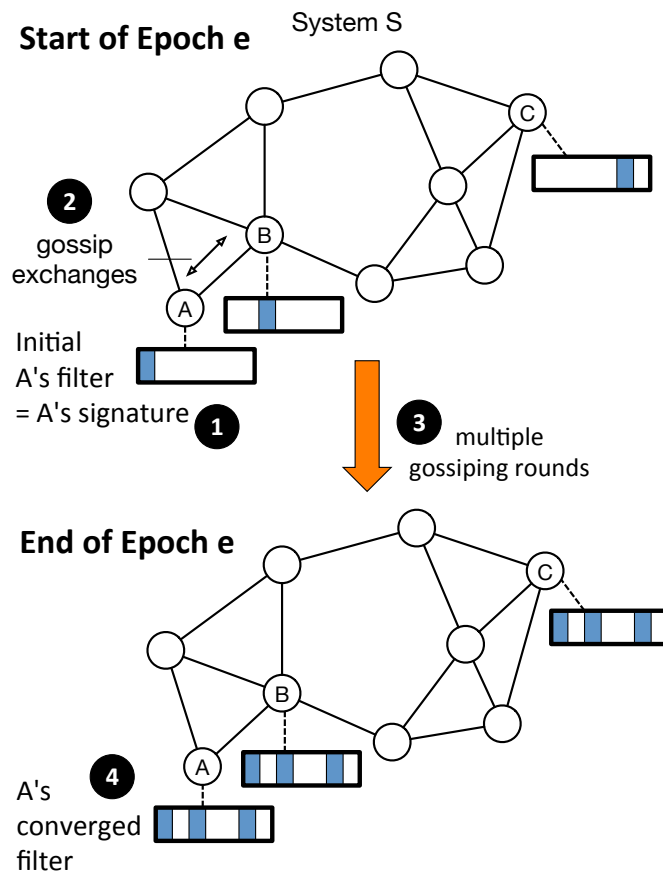
## ■ Example scenario: MANET deployed in adverse environments

- ▶ Emergency teams on disaster area
- ▶ Remote environments with no connectivity
- ▶ Favor end-to-end routing using ad-hoc routing (cheap in energy)
- ▶ Switch to external infrastructure under partitions (costly)
  - Example: deployment of a FANET (Flying Adhoc Network – swarm of drones)
- ▶ Autonomous overlay adaptation

## ■ Under review

# Partition detection and repair

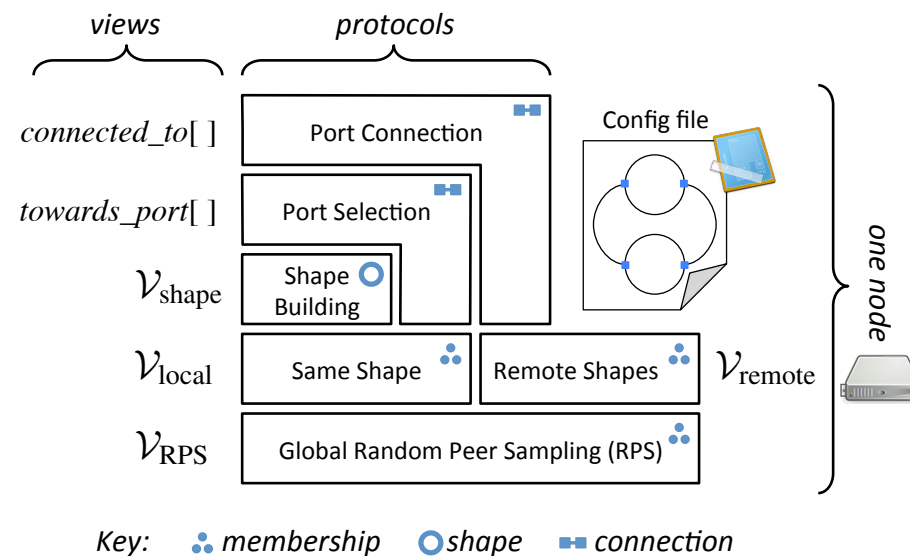
Detection based on aggregation and comparison of system signatures over time



# Declarative overlay composition

## Pleiades framework [DSN 2018]

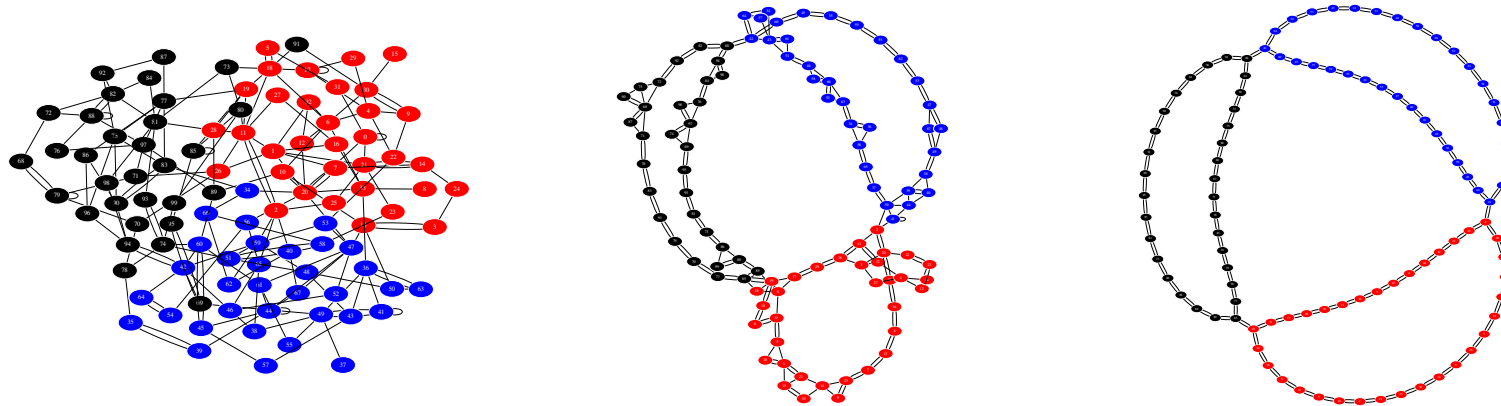
- ▶ Complex overlay system defined as composition of elementary shapes
- ▶ Declaration of structural invariants
- ▶ Autonomous construction and repair
- ▶ Combination of self-stabilizing protocols
- ▶ Domain-specific language for composition specification



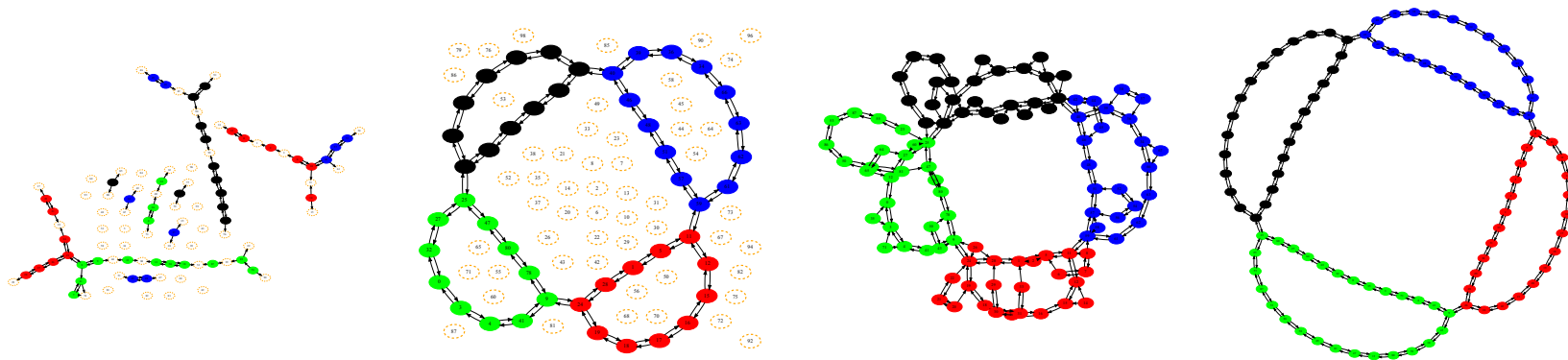
# Declarative overlay composition

## Pleiades framework [DSN 2018]

### ► Emerging shapes

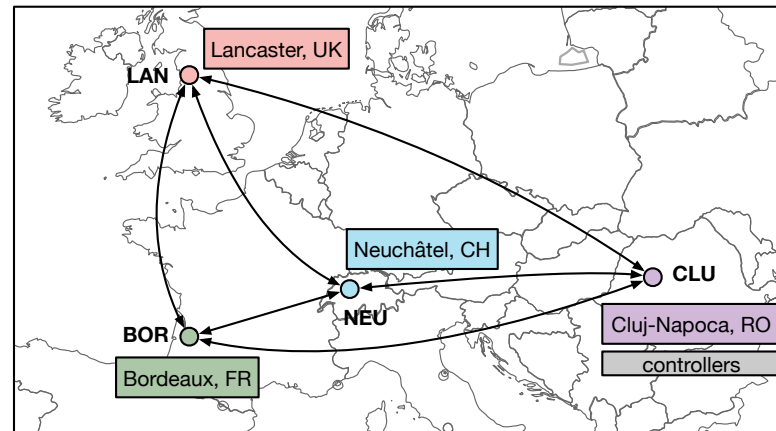


### ► Self-repair after network partition



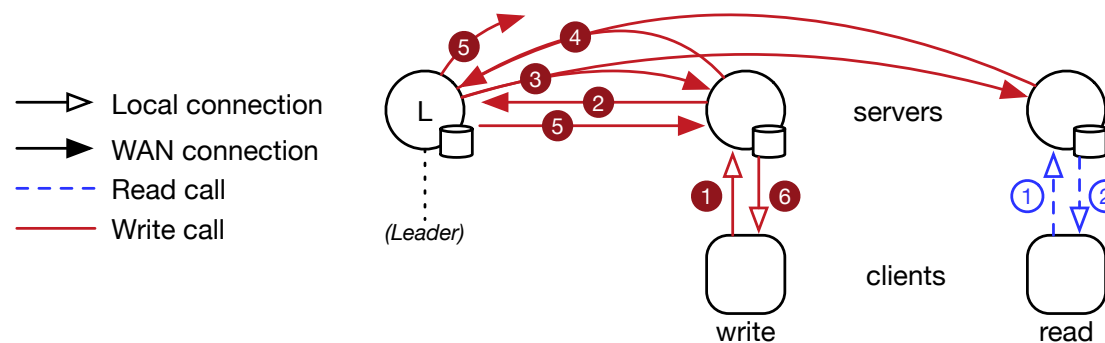
# Overlay adaptation for geo-replicated storage

## Multi-site cloud testbed with NFV support



## Geo-replicated ZooKeeper: disaster tolerance and local *reads*

- Impact of WAN link due to strong consistency for writes

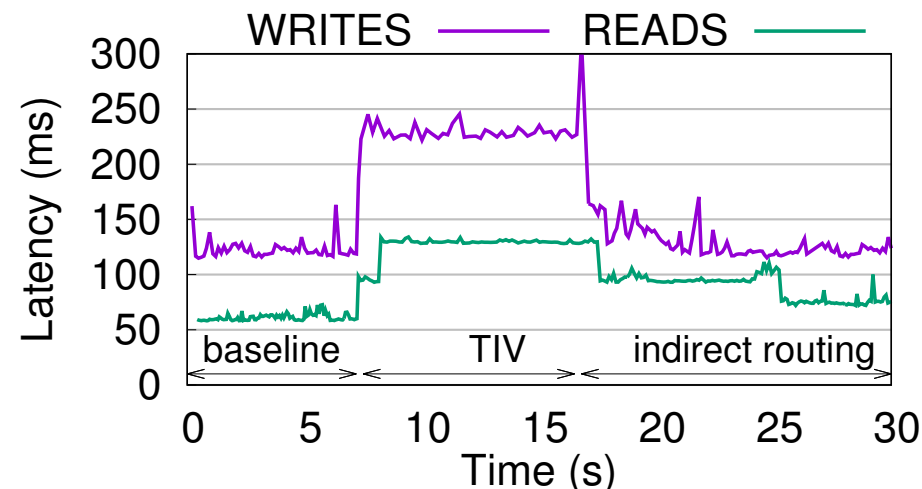


## Edge control of network traffic and application of *indirect routing*

- ▶ Open vSwitch at the 4 sites, SDN controller
- ▶ Traffic and QoS monitoring to detect Triangle Inequality Violation (TIV)
- ▶ *Indirect routing* mitigates performance impact on coherence protocol
- ▶ Dynamic changes in overlay layout without application reconfiguration

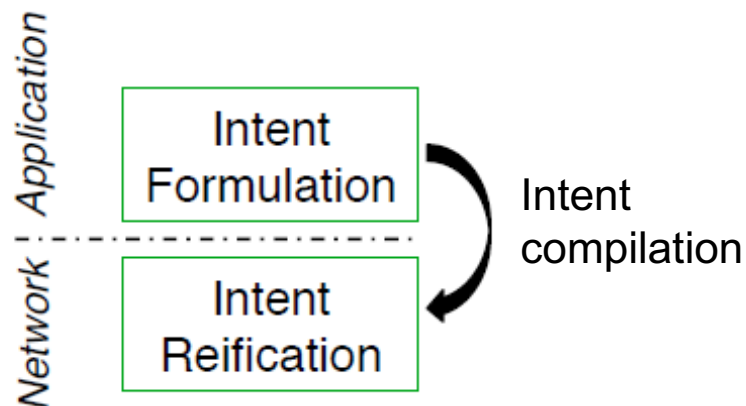
## Published [LANMAN 2017], current work:

- ▶ Automatic adaptation using SDN controller
- ▶ Adaptation for microservice-based applications deployed in edge clouds



# Intent-driven networking

- Problem: network layer only sees use of overlay links without indication of non-functional properties
  - ▶ QoS, priorities, expected flow lifetimes, ...
- Intent-driven networking: hints from app. layer to optimize networking
  - ▶ Application-driven overlay adaptation at the network level
  - ▶ Incrementally-deployable design
  - ▶ Published [CNSM 2017] and ongoing developments



- 20 scientific publications (journals and conferences)
  - ▶ Distributed systems
  - ▶ Networking
  - ▶ Software engineering
  - ▶ Dependability
- 20 scientific publications (journals and conferences)
  - ▶ + 2 under review
  - ▶ 5 in collaboration between institutions
  - ▶ 7 in collaboration with external institutions
  - ▶ 7 single-partner publications
- Organization of two workshops (cross-cloud & ARM) together with major systems conferences (ACM Middleware & EuroSys)

# THANK YOU!

<http://www.dionasys.eu>



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