RAP
Communication Networks, Algorithms & Probability Theory

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Presentation

INRIA Team

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External Collaborators

H. Mohamed	Ass. Prof. Paris X
F. Guillemin	Orange Labs engineer
D. Tibi	Ass. Prof. Paris VII

RAP: General Objectives

- **Design of Algorithms for Networks.**
  Collaboration with Orange Labs.
  Significant Data Sets

- **Development of Mathematical Methods**
  To Study Performances of Algorithms
  Scaling Techniques of Stochastic Processes

Collaboration with Orange Labs

At the origin of the creation of RAP in 2004

- **Collaboration on Few, Focused Research Topics**

An Overview of the Evaluation Period

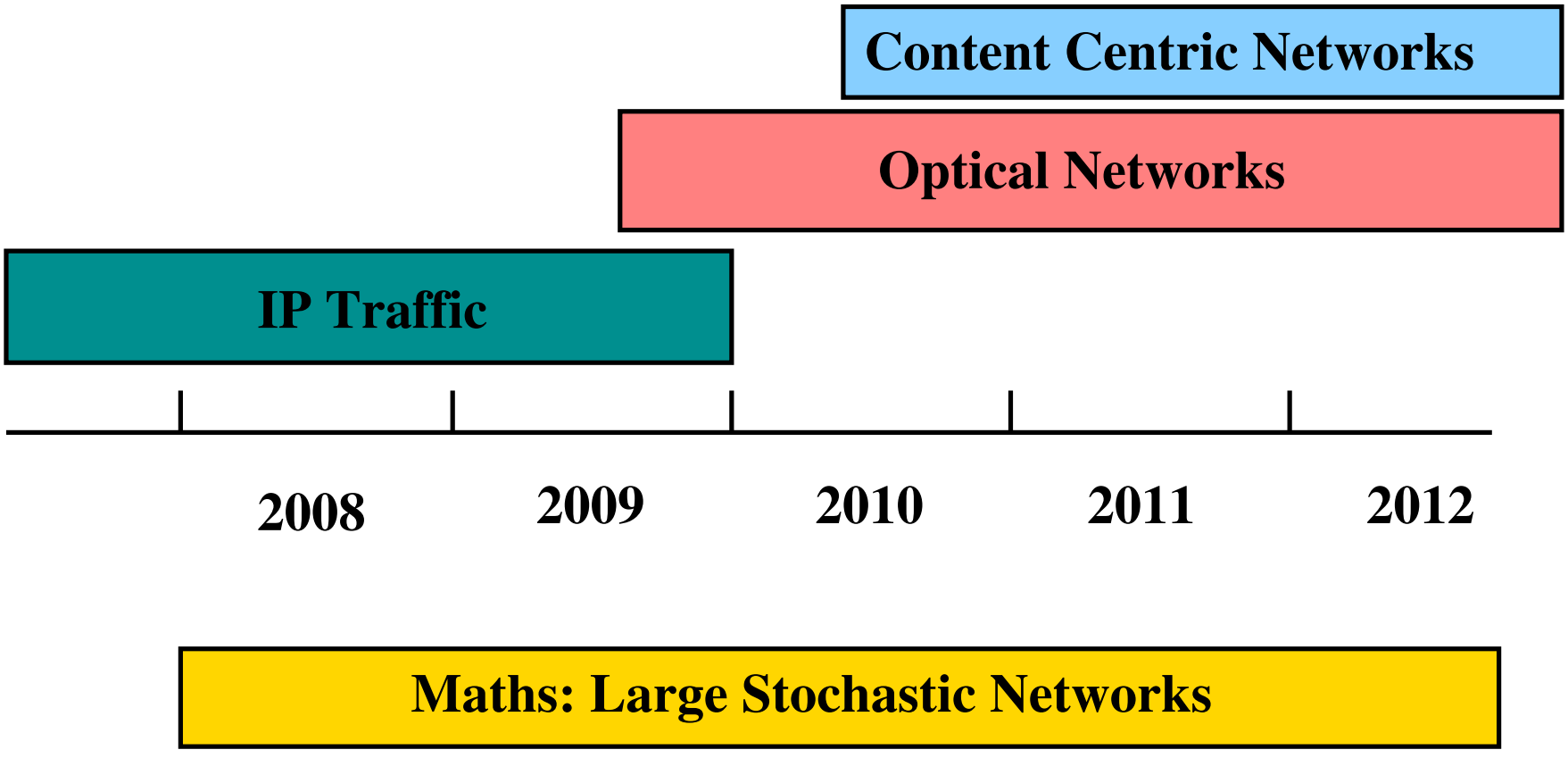
Algorithms

- IP Traffic Attack Detection
- Optical Networks Bandwidth Allocation
- Content Oriented Networks
  Traffic Management and Caching

Probability

- Large Stochastic Networks
  Mean Field and Interaction of Time Scales

An Overview of the Evaluation Period



Bandwidth Allocation in Optical Networks

Efficient Optical Networks
General Problems

- One light path on a given wavelength
- Light cannot be stored at nodes
- Highly dynamic context of the Internet
  $\Rightarrow$ No complicated static assignments of light paths.

A Dynamic Bandwidth Allocation (DBA) Problem

Optical Networks
The Pb. of Technological Assumptions

- Number of Transmitters/Receivers at sources/destinations ?
- Tunable Transmitters/Receivers ?
- Use of Delay Lines ?
- Large Nb of wavelengths ?
- Wavelength Conversion at Nodes ?
- ...

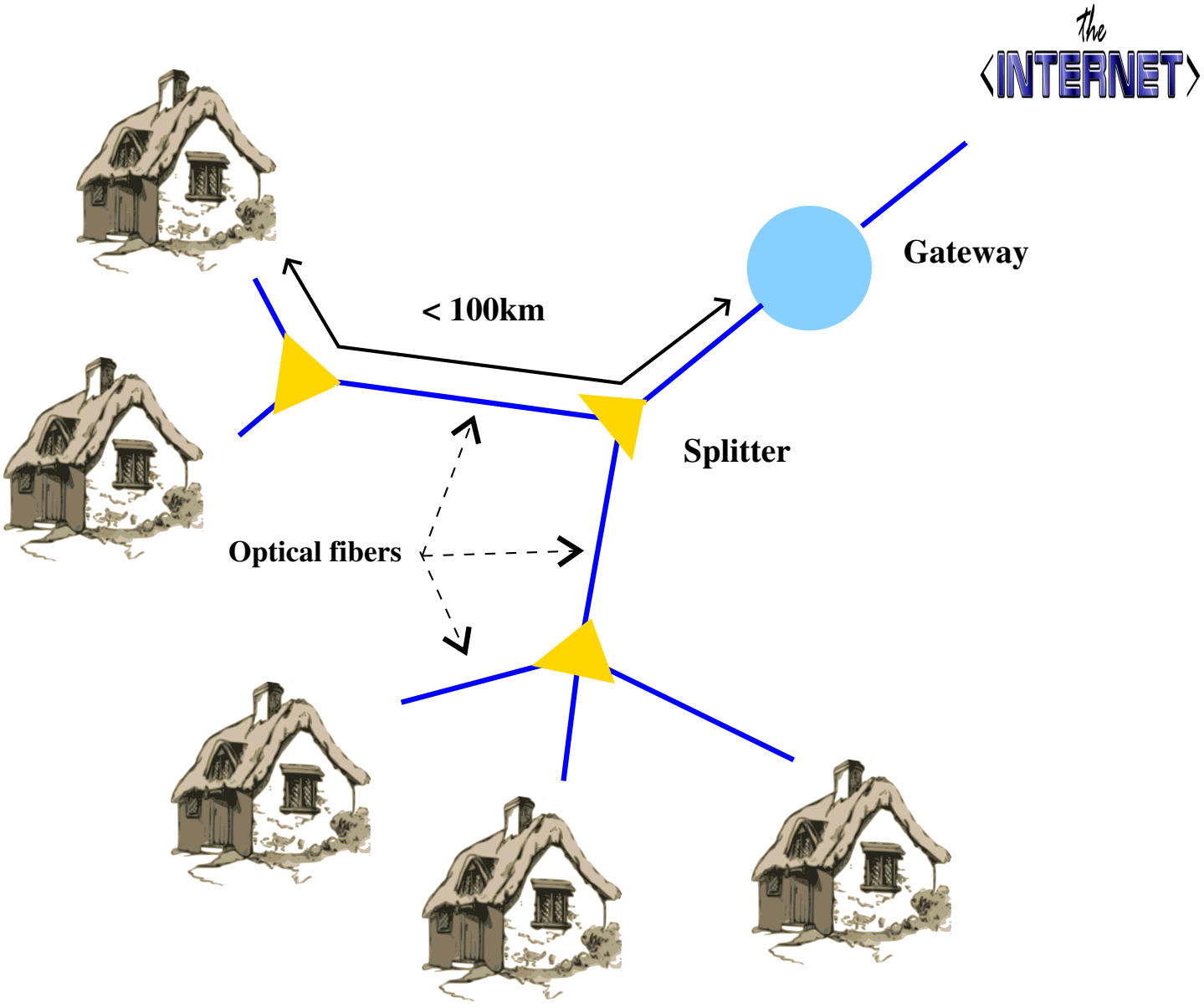
$\Rightarrow$**Strong impact**
on the design of DBA Algorithms.

Optical Networks
Assumptions for our Studies

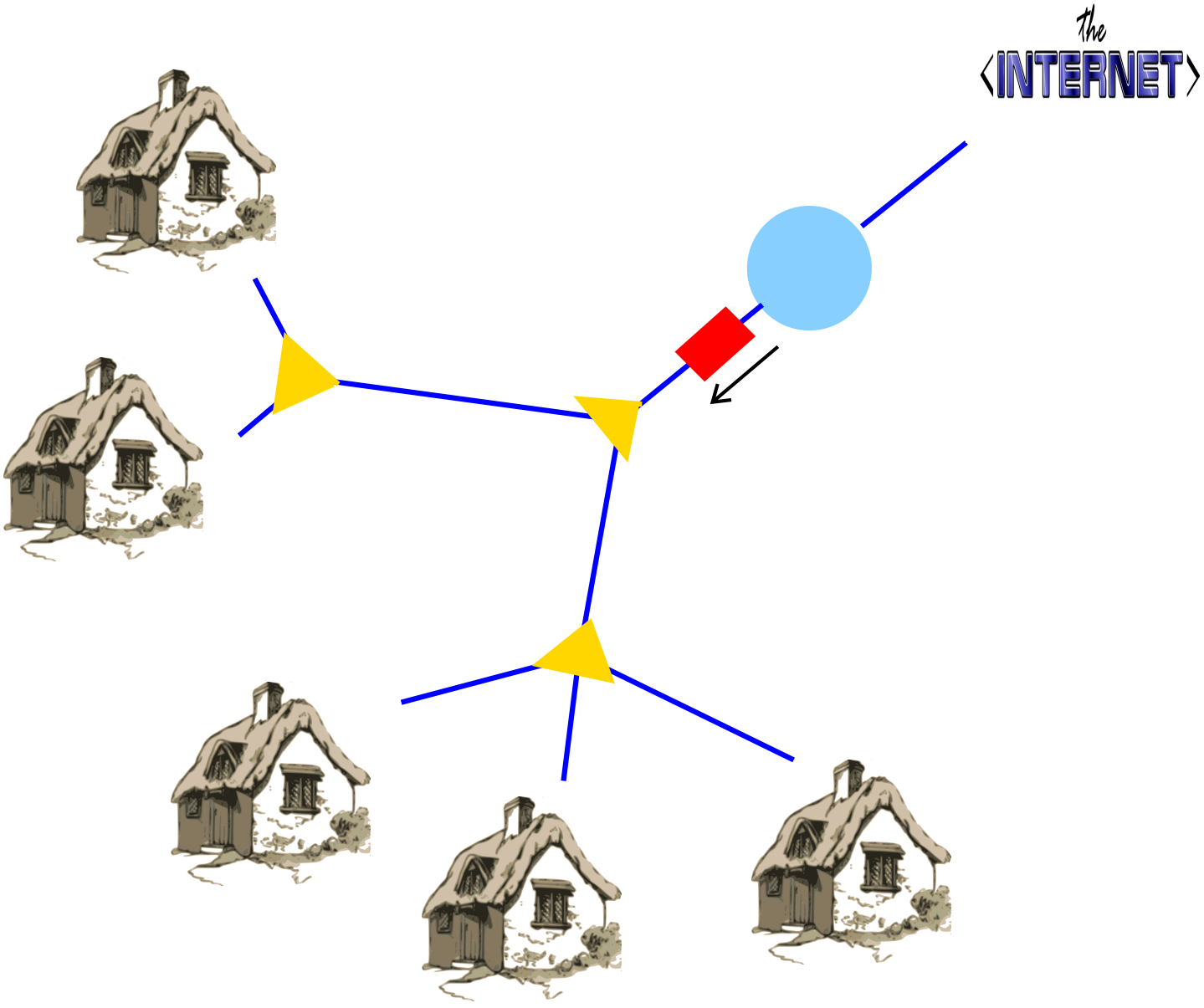
Simplest Setting to start with

- **Passive components**
- **Algorithm for one wavelength**

Optical Networks: PON



Optical Networks PON: Downward



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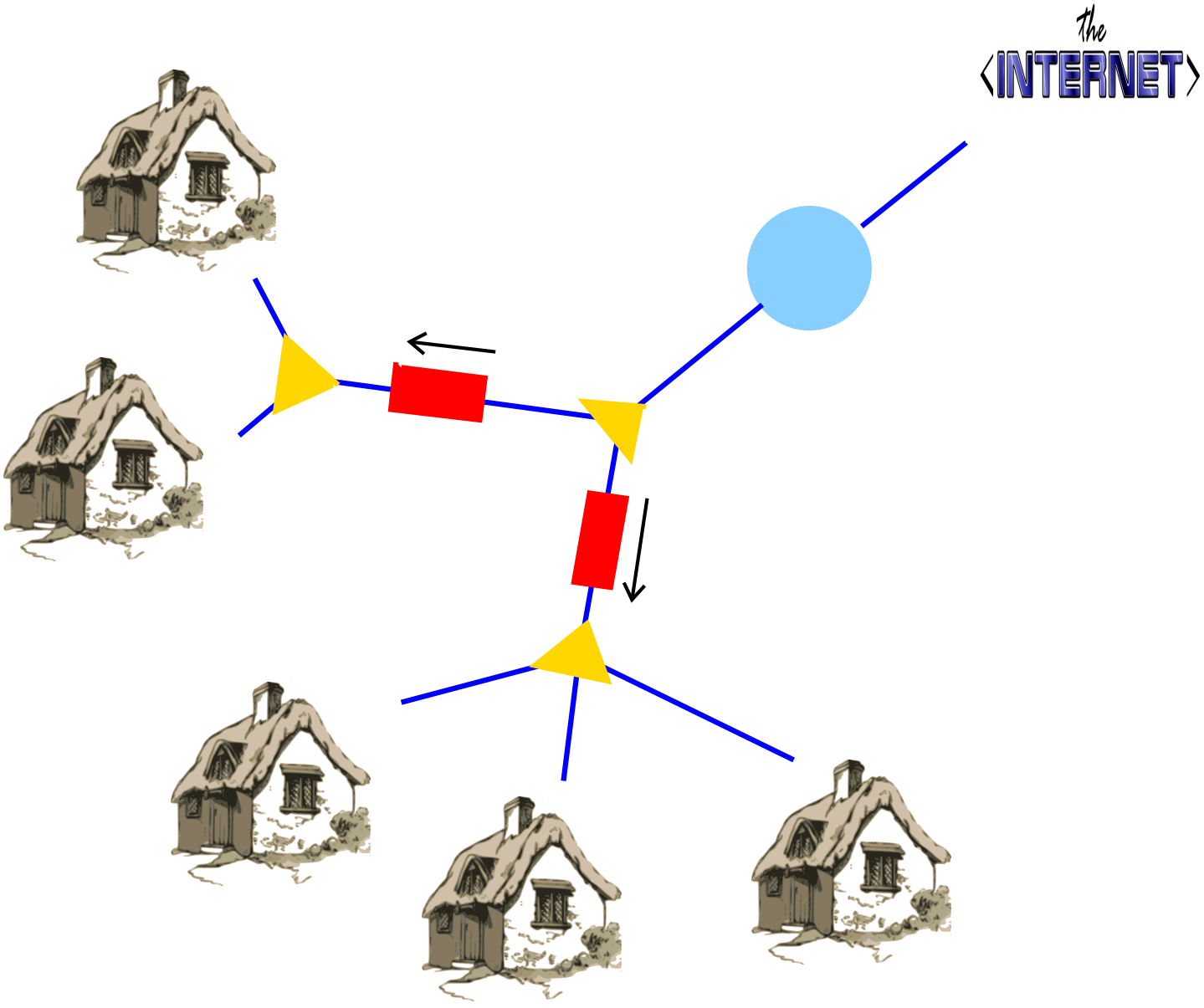

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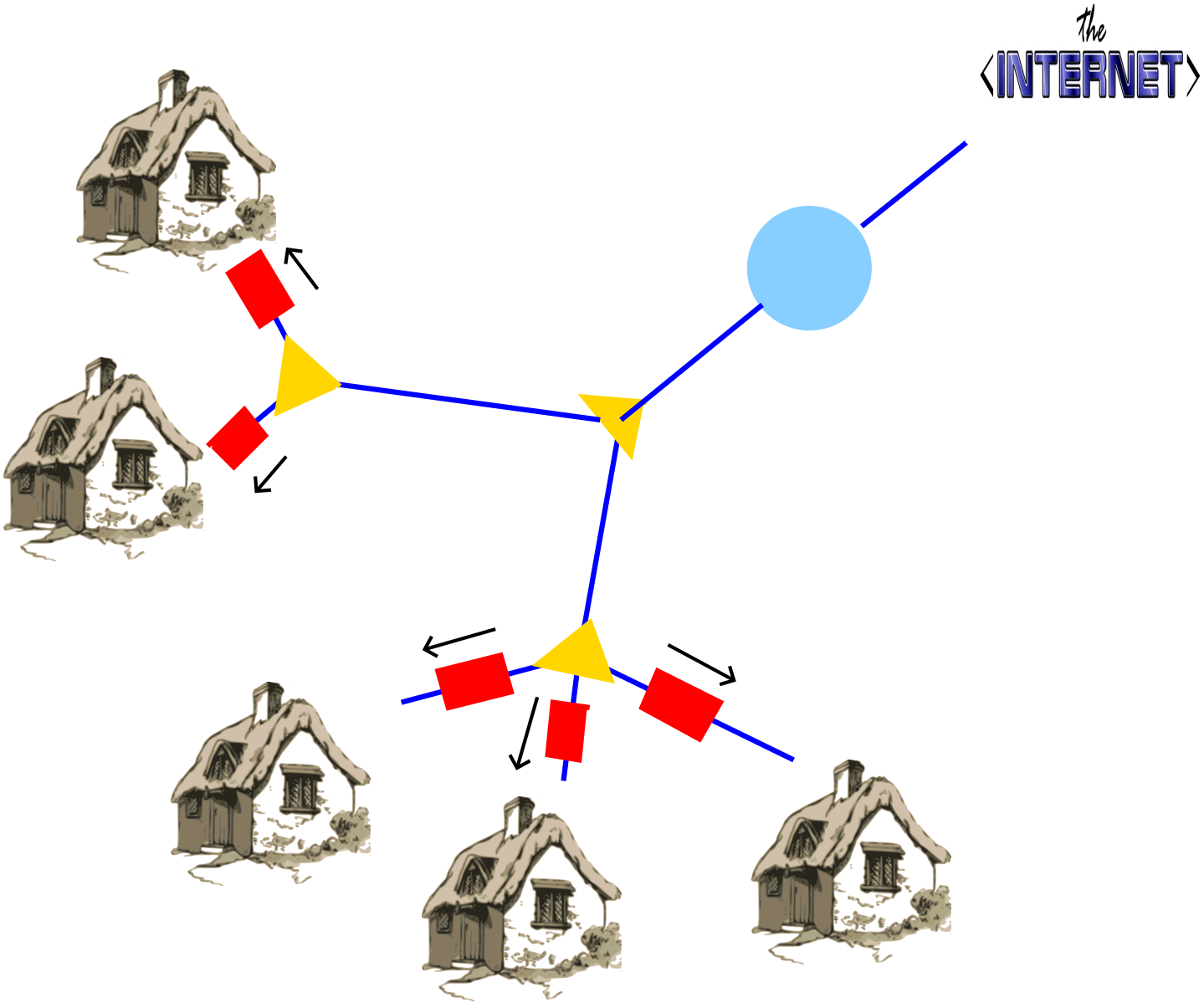

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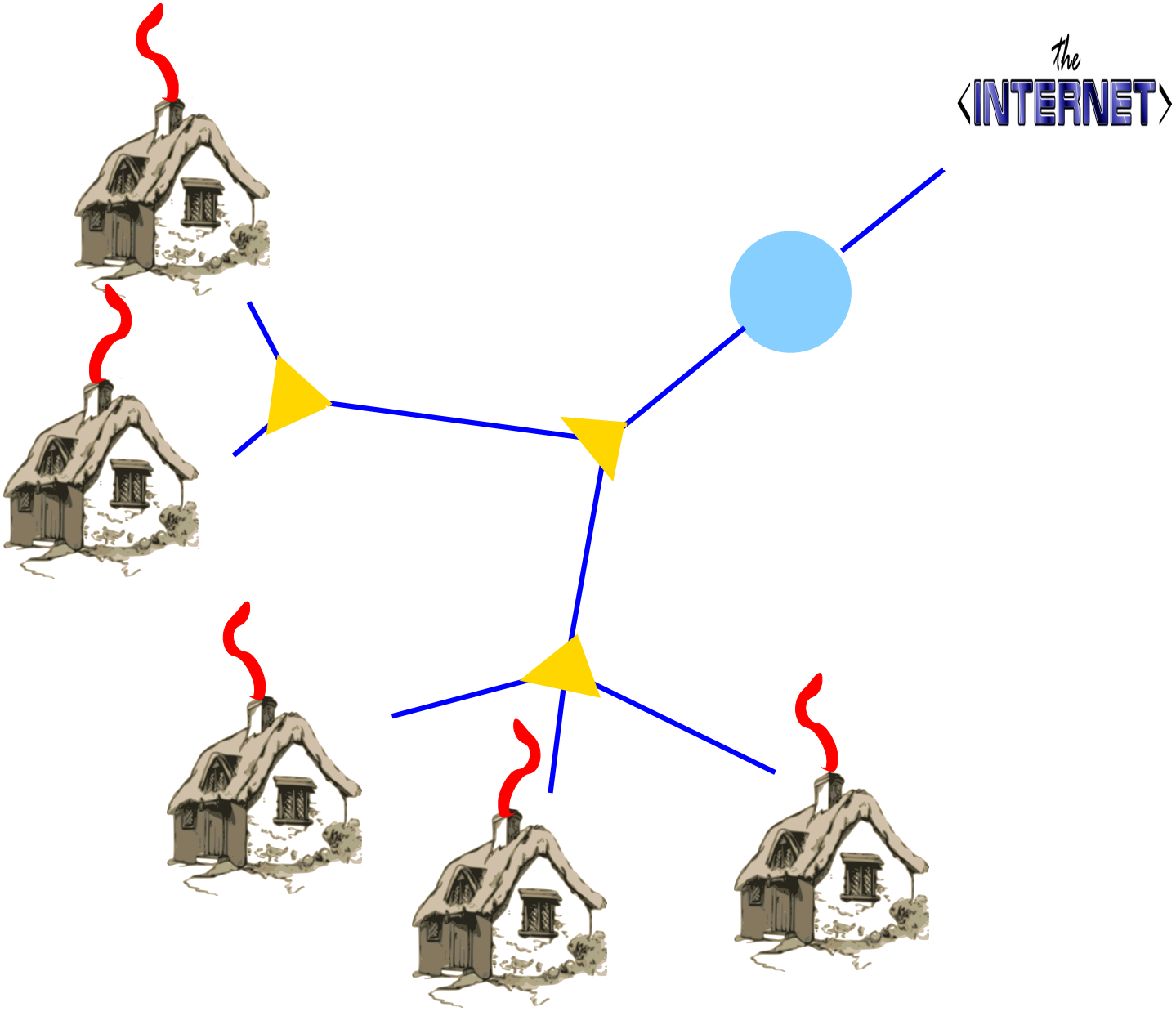
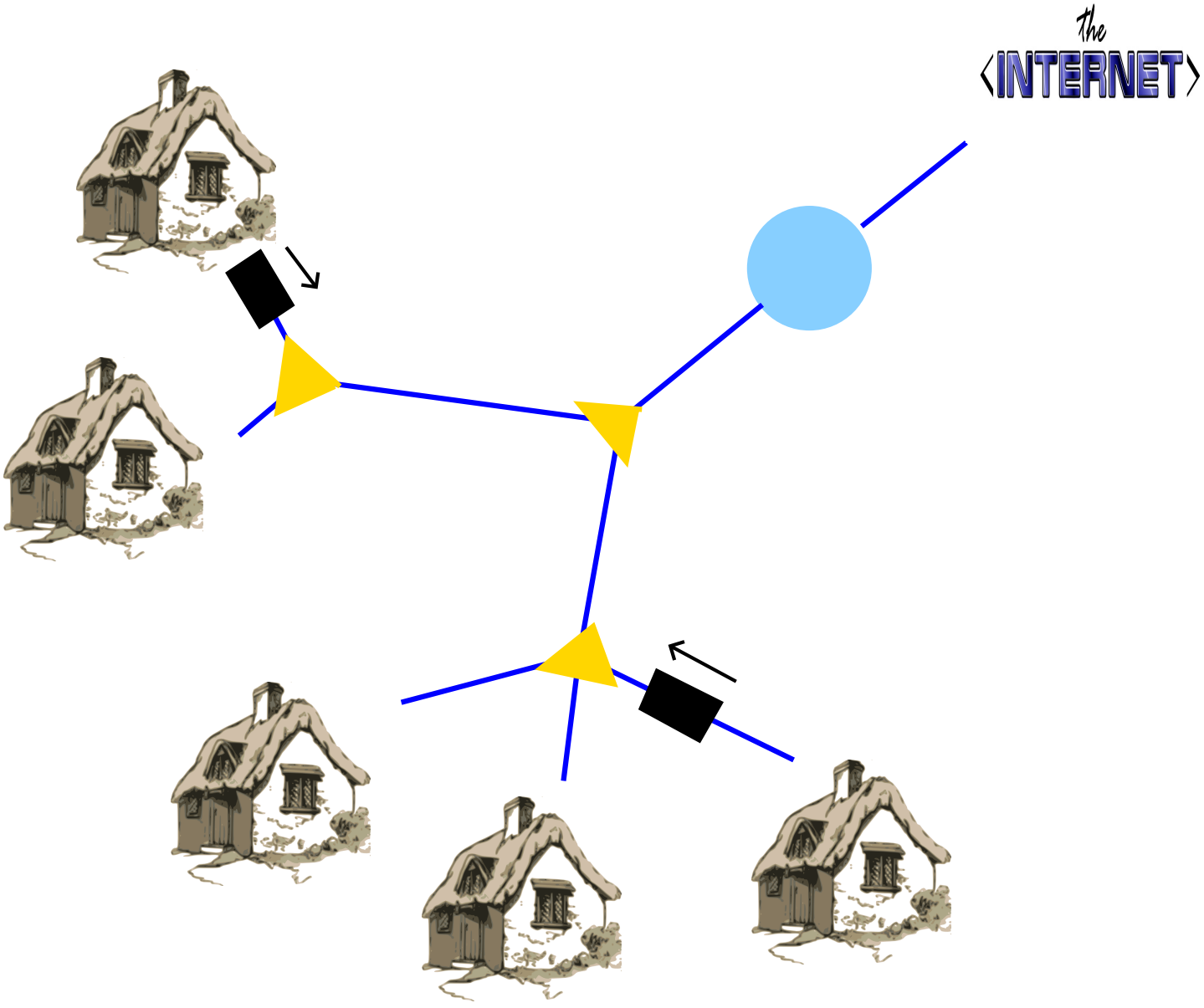
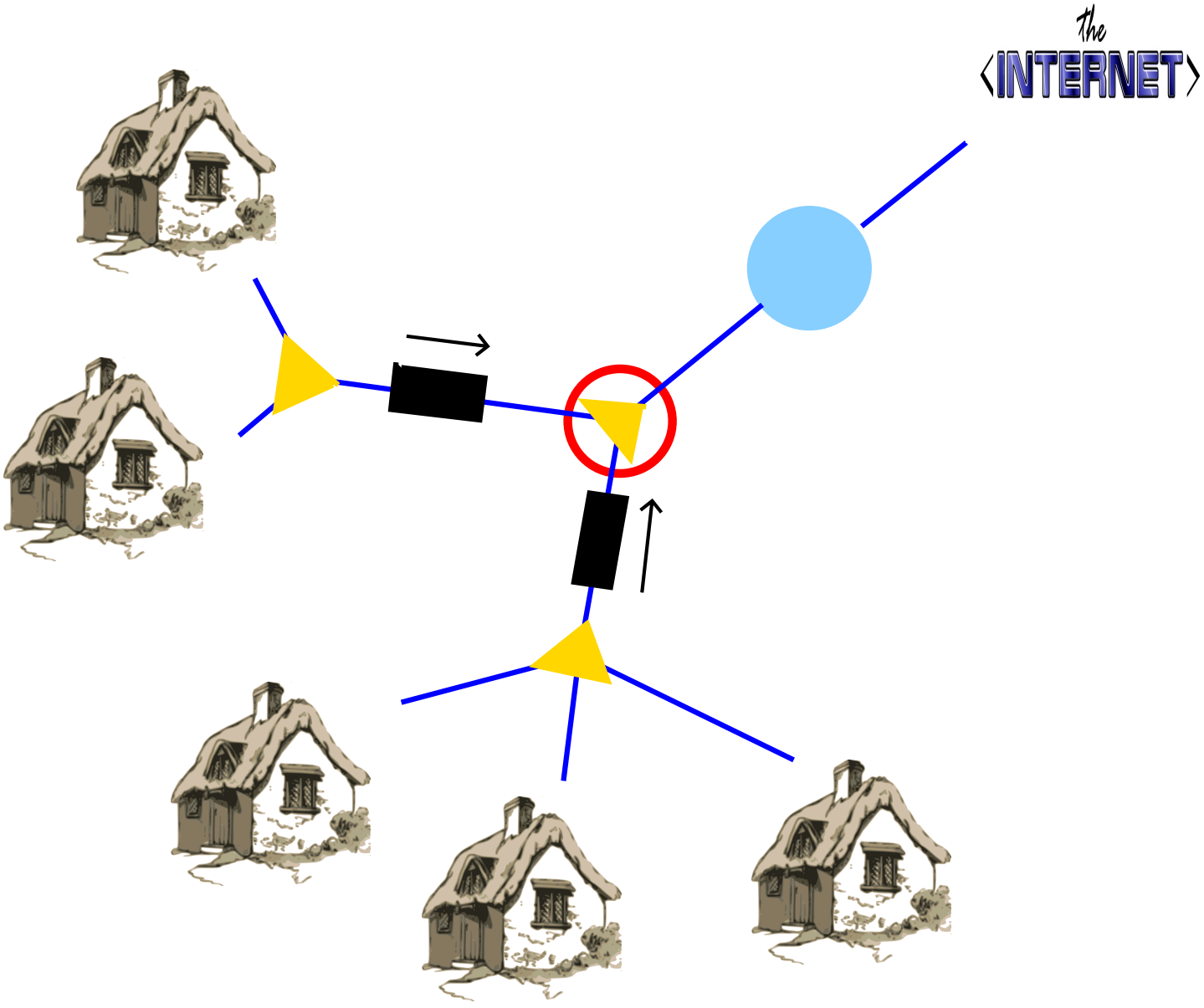


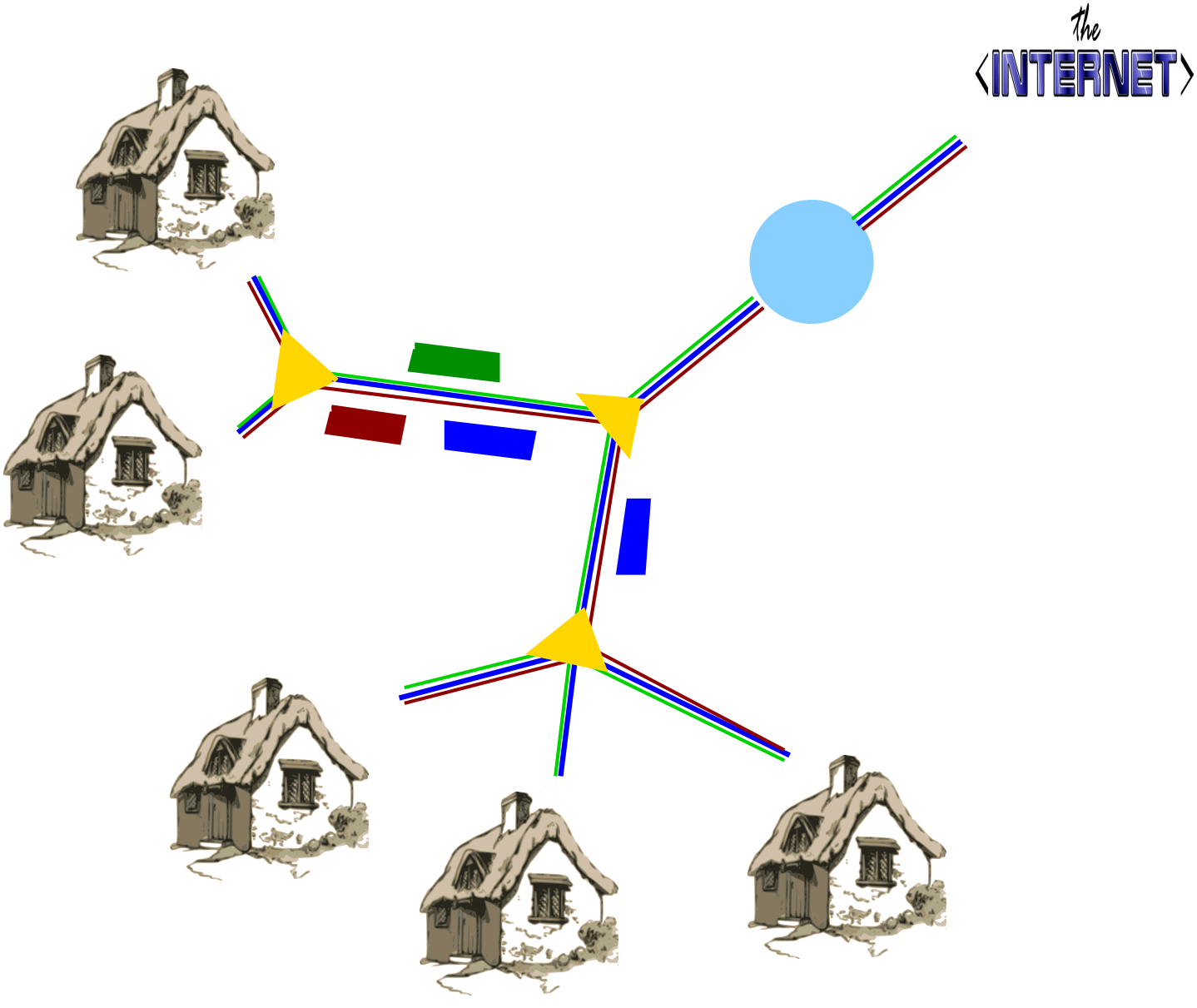
Optical Networks PON: Upward



Optical Networks PON: Upward



Optical Networks PON
Multiple Wavelengths



Optical Networks PON
DBA for Upstream

Basic mechanism: Gateway (GW) controls access

- Terminals send reports to GW.
  Report: QUEUE-SIZE

- GW issues grants to each terminal.
  Grant: Begin-Time/End-Time

Problems for current DBA algorithms:

- Performances depend on distance to furthest terminal.

Optical Networks PON
An Original Bandwidth Allocation

Basic Ingredients

- **Adaptive Cyclic Algorithm.**
- **Dynamic Allocation of Grants.**

$\Rightarrow$ **Maximal Capacity Region.**

Optical Networks: Extensions

- **Mesh Networks**
  TWIN (Alcatel-Lucent) + our EPON DBA

- **Wide Area Networks**
  $\Rightarrow$ **Multipath Algorithm**
  Patent with Orange Labs

Extension to Mesh Networks
Analysis of Performances

Stochastic Models: Complex Polling Systems

- **Multiple Servers (Wavelengths)**
- **Constraints on Location of Servers**

Tools to Investigate Capacity

- **Fluid Limits**
- **Mean-Field Results**

Content Centric Networks

Content Centric Networks

A New Paradigm for Internet (van Jacobson)

- Network does not connect nodes but provides Contents (Objects)
- Traffic: Interests and Data
- Additional Security Features
- A Software: CCNx

Content Centric Networks: Context

ANR Connect project with

- Alcatel-Lucent
- Orange Labs
- INRIA PLANETE + RAP Teams
- Telecom ParisTech
- Université Pierre et Marie Curie

Content Centric Networks: Caching

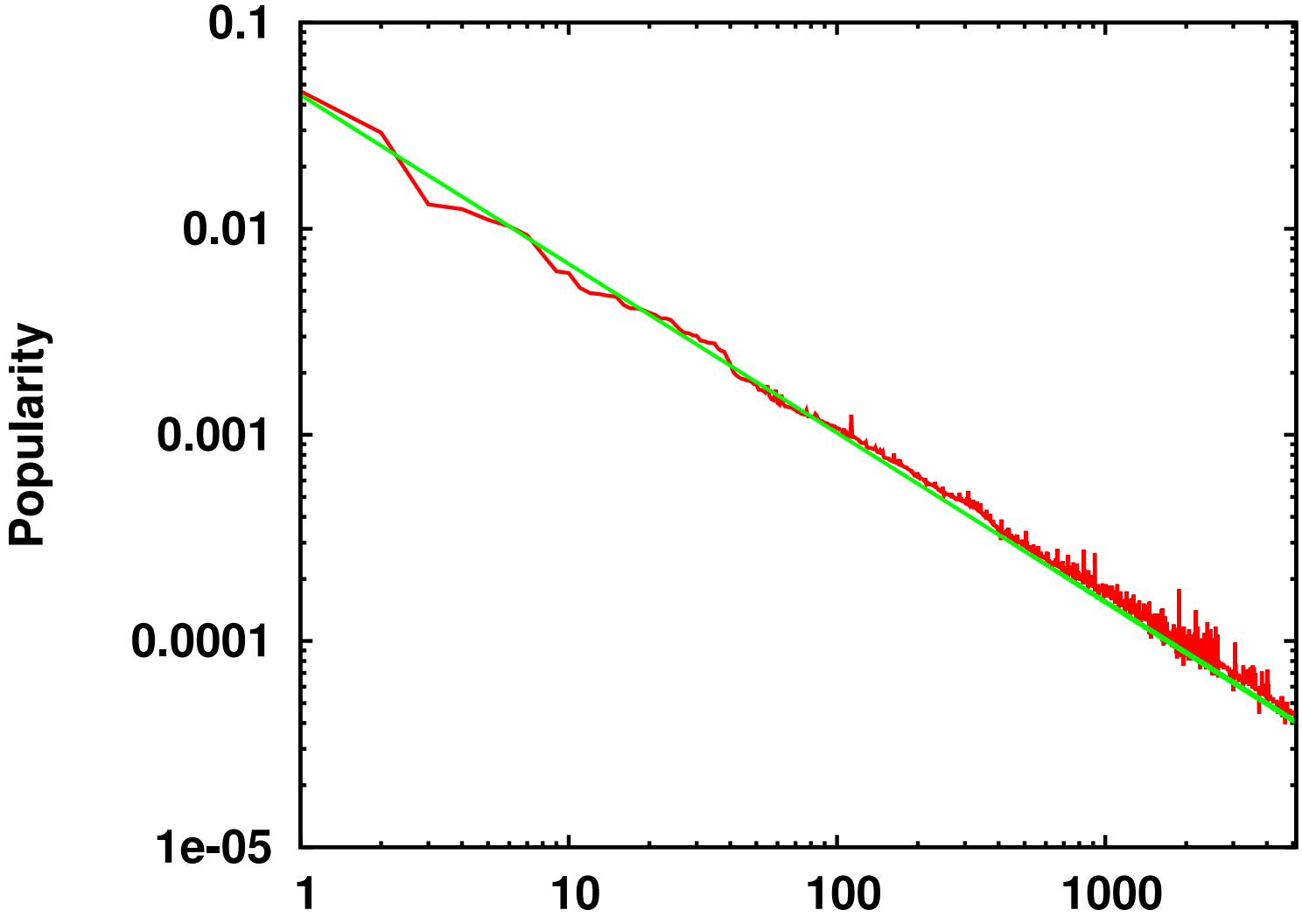
Contents may be stored in caches

Parameters

- **Architecture/Sizes of caches**
- **Popularity Distribution of Contents**
- **Caching Policy**

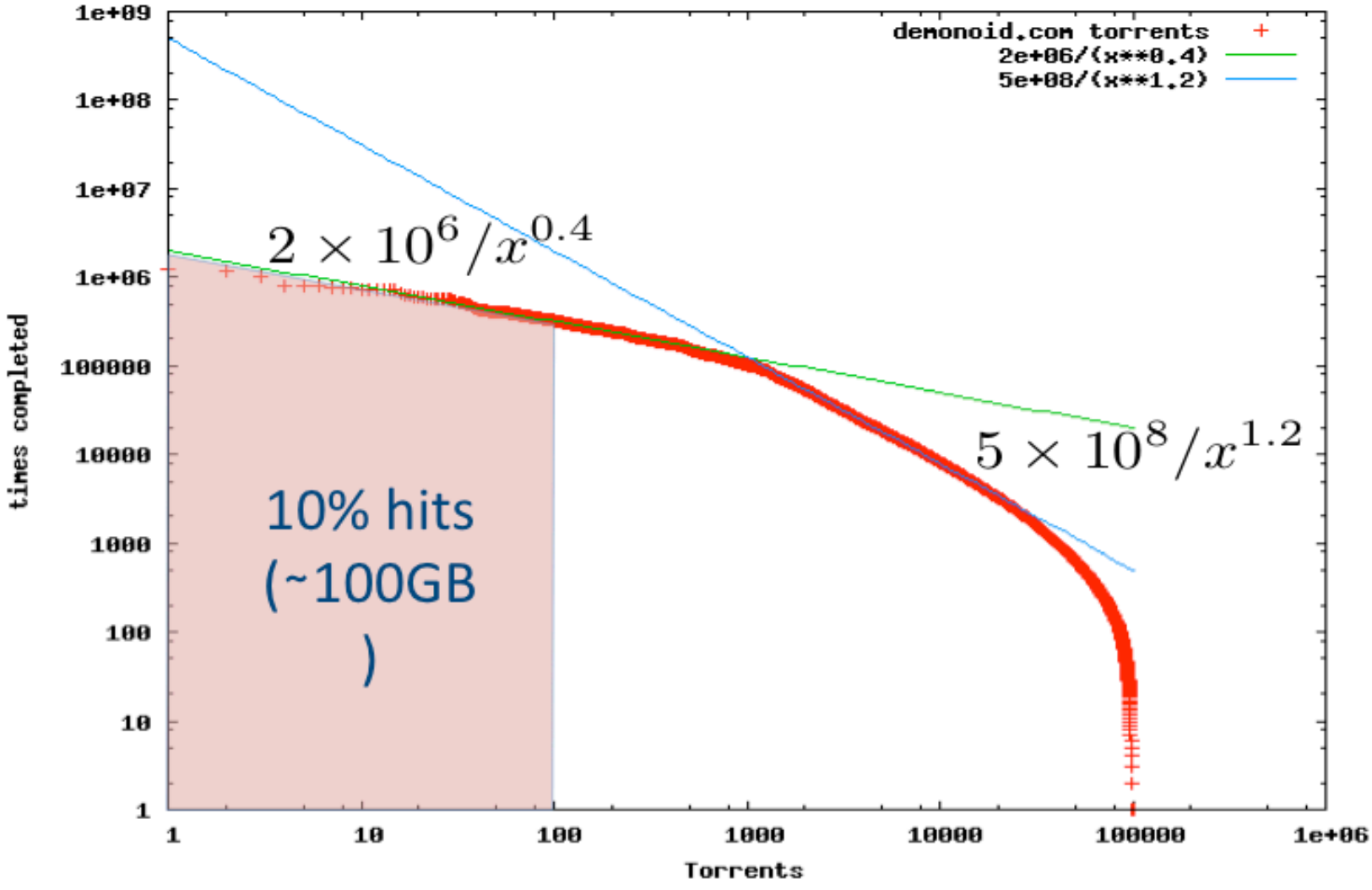
Some Data on Popularity Distributions

A Torrent Site: demonoid.com



Popularity close to $x \mapsto C/x^{0.82}$

Some Data on Popularity Distributions
Impact of Caching



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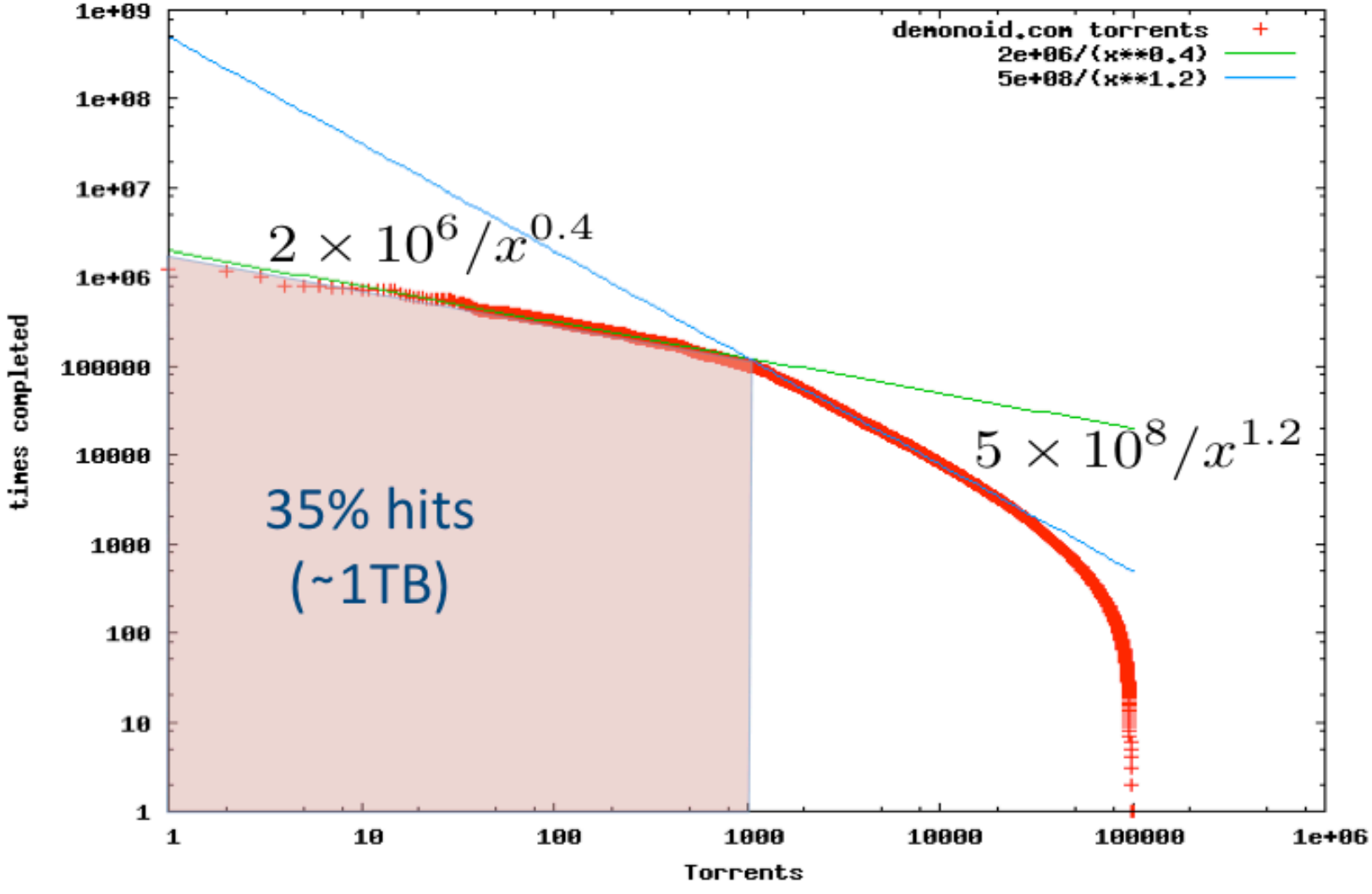

Caching in Content Networks

Large of orders of magnitude

P-Byte: 10^{15} Bytes

	population size	mean object size	overall volume
Web	10^{11}	10 KB	1 PB
File sharing	10^{5}	10 GB	1 PB
UGC	10^{8}	10 MB	1 PB
VoD	10^{4}	100 MB	1 TB

$\Rightarrow$ **Very very large caches**

Content Centric Networks
RAP's Contributions

- **Design and evaluation of traffic controls**
  How to do without TCP
  Fairness and Service Differentiation
- **Design and Evaluation of Replication and Caching Strategies**
  Architecture to Store Contents
  Estimation of Hit Ratios

Scaling Methods for Stochastic Networks

RAP's Toolbox

Scaling Methods

Two Topics

- **Mean-Field**
  Dynamical Systems — Stability Issues

- **Interaction of Time Scales**
  Fluid Scalings
  Stochastic Averaging Principles

Scaling Methods (I)
Mean-Field

Network with Large nb of Interacting Nodes

- **Nb nodes** $\nearrow +\infty$
- **Behavior of a "typical" node ?**

Evaluation Period: used to estimate

- **Algorithms for IP Traffic**
- **Bandwidth Allocation in**
  1. Optical Networks
  2. IP Networks
  3. Mobile Networks
- **Bike Sharing Systems (Velib)**

Scaling Methods (II)
Interaction of Time Scales

- Different Time Scales
  drive behavior of a network (sometimes)
- Time Scales interact !

Evaluation Period

- Optical Networks
- PageRank Algorithms
- DHT (Storage Systems)
  Collaboration with INRIA Team REGAL
- Bandwidth Allocation in IP Networks

Interaction of Time Scales
Stochastic Averaging

New examples

- Bandwidth Allocation in IP Networks
- DHT (Storage Systems)

Evaluation Period: Methods

- Significant Simplifications
- Some technical problems
  underestimated in current literature

Software

- **Attack Detection Software Prototype**
- **PON Simulator**
- **Forwarding Strategies in CCN Networks**

Collaborations

- **INRA**
  PhD thesis on queueing network models to study protein production
- **Université Paris Denis Diderot,**
  Pierre et Marie Curie,
  Paris Ouest Nanterre La Défense
- **École Polytechnique, Telecom ParisTech**
- **CWI, Un. Twente, Stanford, Helsinki, Eindhoven, . . .**

Industrial Collaborations

- **Orange Labs**
  THANKS !!!
- **Alcatel-Lucent**
  ANR Connect & Alcatel-Lucent Bell Labs
  INRIA/Alcatel-Lucent Lab ?

Future Work

Optical Networks: Future work

- Multipath Algorithm at the Core
- Capacity of Multipath Algorithm
- Optical Technology in Data Centers

- European Project Proposal
  CELTICS-+ SASER with Orange Labs,
  Alcatel-Lucent, Siemens, Telecom Inst...
  Experimentation of Multipath Algorithm

Information Centric Networks (ICN)

- Architecture of ICN with Data Centers
- Impact of Cache Hierarchies
- Cache Size vs Bandwidth

- Collaboration with INRIA MAESTRO
- European Project Proposal: FP7-Scot with University of Eindhoven, CWI, Alcatel-Lucent, ...

Mean-Field (MF) Results

A generic problem:
CV of Equilibrium in the MF limit ?

Further Examples of MF

- **Bike Sharing Systems with Geometry**
- **Equilibrium of Optical Networks**
- **Production of Proteins in Bacteria**

Interaction of Times Scales
Stochastic Averaging

Again a generic problem:
Regularity of the continum of invariant distributions ?

Examples

- **Bandwidth Allocation Algorithms**
- **DHT with geometry**

C'est la fin