The Effectiveness of Realistic Replication Strategies on Quality of Availability for Peer-to-Peer Systems

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Goals

Understanding & Satisfying

Availability for peer-to-peer (P2P) Systems,

i.e.

- **maximizing P2P requested service time**
- **satisfying different availability requirements for different peers**

or

- **given**
  - set of availability demands
  - (finite) network topology
- **find out**
  - what to replicate?
  - how many replicas?
  - where to locate replicas?
  - when and how to replicate?

Overview

1. **Motivation**

2. **Quality of Availability (QoA)**
   - Concept and Definition
   - QoA Notion - Availability Refinement

3. **Replication for QoA**
   - Problem
   - Placement Algorithms

4. **Simulation Study**
   - Improving QoA - dynamic & partial replication

5. **Conclusion**

Motivation

Selected Characteristics of P2P Systems

- Peers go up/down independently of each other
- Peers are symmetric in terms of supplying and demanding services
- Different peers supply different levels of service availability
- Different peers demand different availability levels

CHALLENGING RESEARCH ISSUES

⇒ **Offer the service differentiation for peers or p2p applications in the availability context**

⇒ **Devise mechanisms and algorithms to satisfy/provide different levels of availability for individual peers**

Quality of Availability

Basic Idea

- **AVAILABILITY-CENTRIC view on quality of service (QoS)**
  - to treat availability as a controllable QoS parameter
- **replication based on admission control concept**
  - to control & guarantee **QUALITY OF AVAILABILITY** (QoA)

Definition of Quality of Availability (QoA):

„well-defined and controllable availability (behavior) of a service according to the quantitatively measurable parameters such as data availability,nodeavailability,and link availability"

QoA Metrics

Parameter	Definition	e.g.
satisfiedQoA	**for each demanding node, how much availability is fulfilled at the selected placement**	*0.95, 1.05*
$QoA_{sat}(v)$	the ratio of supplied/reached avail. to demanded/required avail. for node v, $\forall v \in V_R$ with V_R = V without R	
QoA_{avg}	$1/n(\sum QoA_{sat}(v))$ $\forall v \in V_R$ and $n = (\|V\| - \|R\|)$	*0.95*

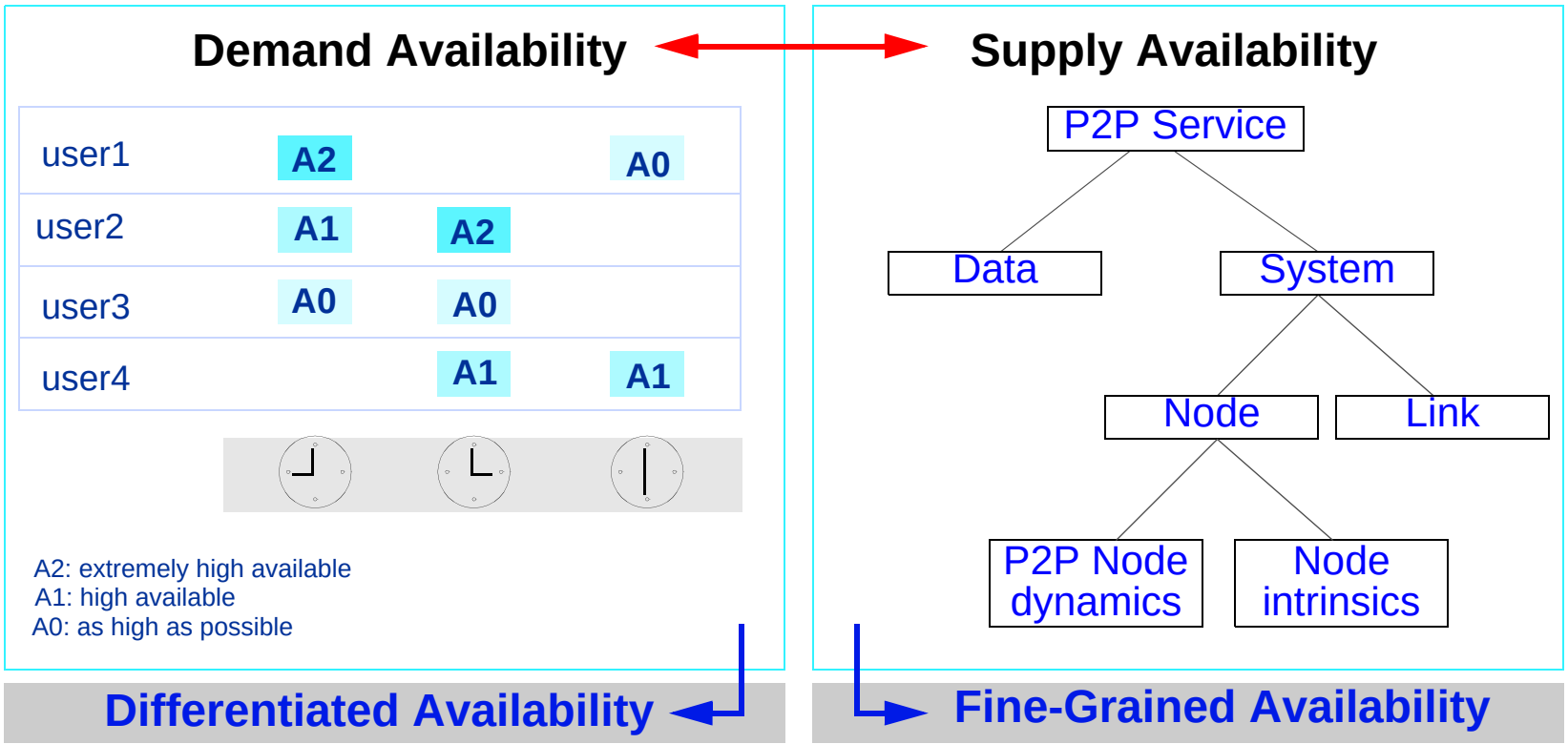
Notion of QoA

Availability: percentage of service uptime, i.e. $\text{Availability} = \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}}$ **but, ...**

Refining Availability Definition

- decoupled: demand vs. supply; perceived & provided - closing the gap
- differentiated: different users, different availability levels
- fine-grained availability:

$$\text{Avail}_{\text{Service}} = \text{Avail}_{\text{Data}} \times (\text{Avail}_{\text{P2Pdynamics}\,\text{Node}} \times \text{Avail}_{\text{intrinsics}\,\text{Node}} \times \text{Avail}_{\text{Link}})$$



Replication for QoA

Main Concern

HOW TO IMPROVE QOA?

HOW TO SATISFY DIFFERENT QOA LEVELS?

Focus

- **to choose dynamically a 'good' placement, i.e.**
  - Selecting target replicas &
  - Choosing their number and location

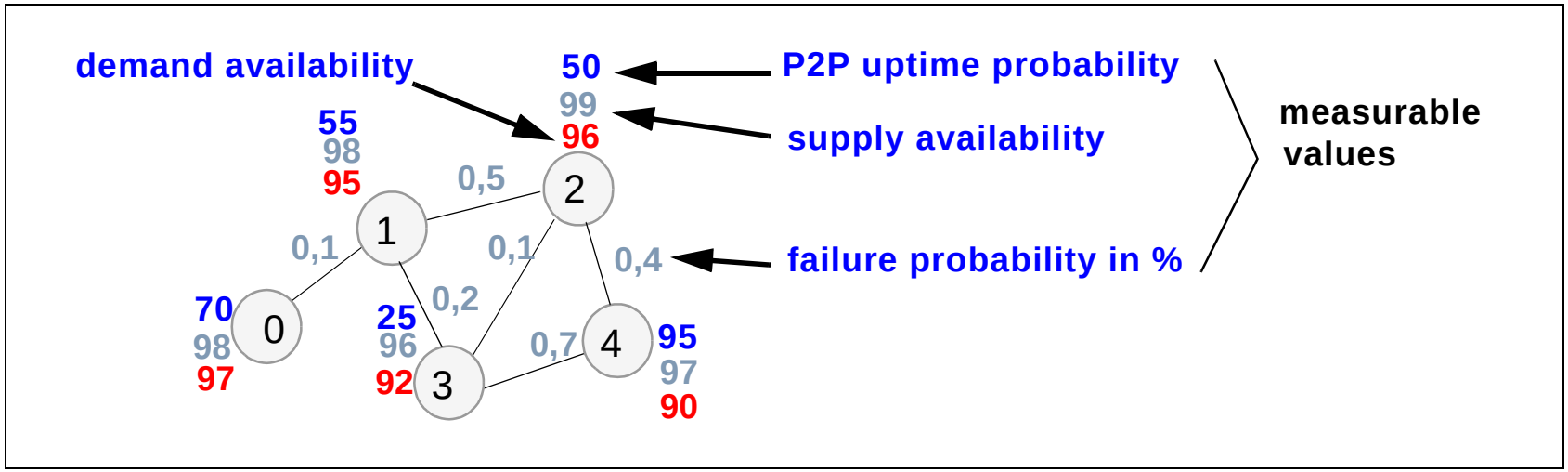
while

- Increasing/Satisfying the QoA requirement for individual users &
- Taking the data/systems' availability explicitly into account

Replication for QoA (2)

Modeling P2P systems

- as **STOCHASTIC GRAPH G(V, E)**
- numbers just as example!



Features

- **Partial replication (i.e. file by file)**
- **Decentralized, on-line placement**
- **Placement in two phases**
  - proactive and on-demand

Placement Strategies

Proactive placement algorithms

- **Random**
- **Popularity-based**

On-demand placement (at run-time) algorithms:

- **Local**
  - i.e. demanding client becomes next available replica (i.e. random)
- **HighlyAvailableFirst (HA)**
  - as computed $QoA_{supplying}$
  - per node:
    $QoA_{supplying}$ * average of all adjacent ($QoA_{link\ availability}$)
- **HighlyUpFirst (UP)**
  - P2P server uptime probability
- **combined HA+UP**

Simulation

Methodology

- **using an event-driven simulation model**
- **used tools - Leda, CNCL**

Assumptions (under P2P constraints)

- **network abstraction for P2P**
  - dynamic (#nodes & #links changes)
  - stochastic (nodes & links attributes)
  - unconstrained (each node can be demanding and/or providing service) graph
- **node and link failure probabilities with/without a prior global knowledge**

Metrics

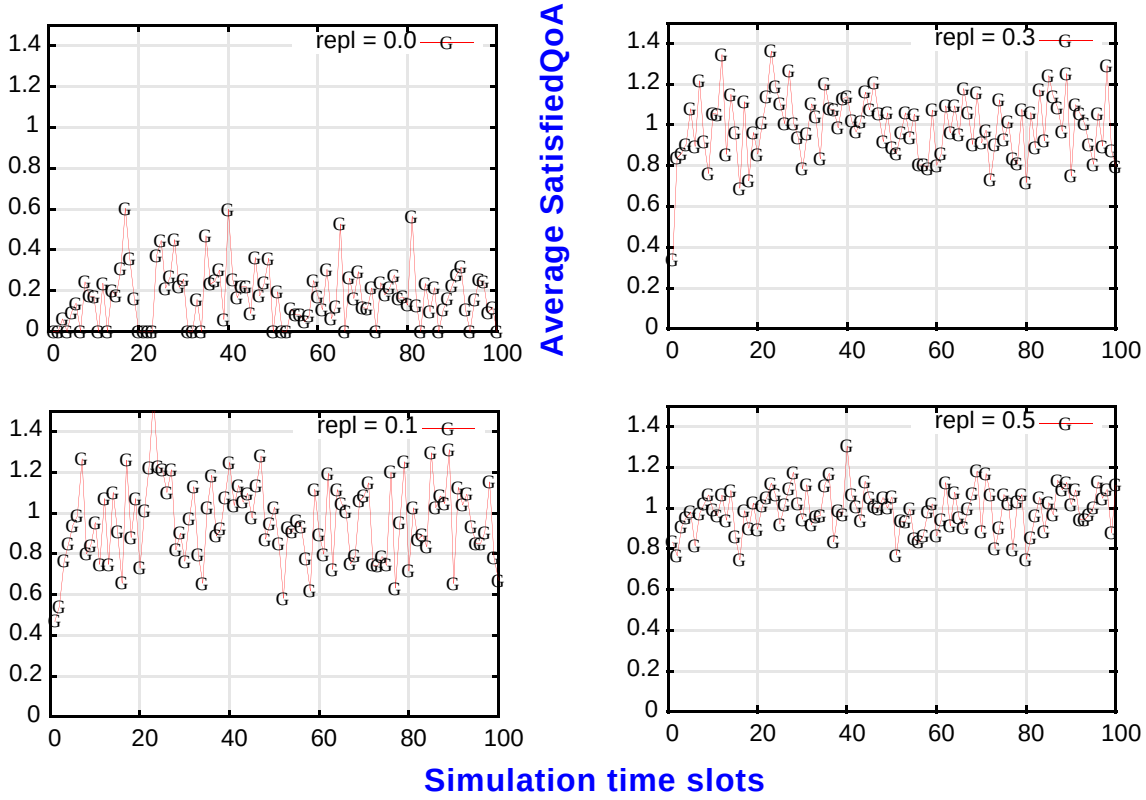
- **SatisfiedQoA**
- **Service availability:**

$$Avail_{Service} = Avail_{Data} \times (Avail_{P2Pdynamics Node} \times Avail_{intrinsics Node} \times Avail_{Link})$$

Effect of |R| and T(R) on SatisfiedQoA

Experiment

- Graph(1000,3000), node: up_prob: 30%, req.QoA: 50-99%, link_fail: 0-10%
- proactive placement: Random, query model: Uniform



Observation

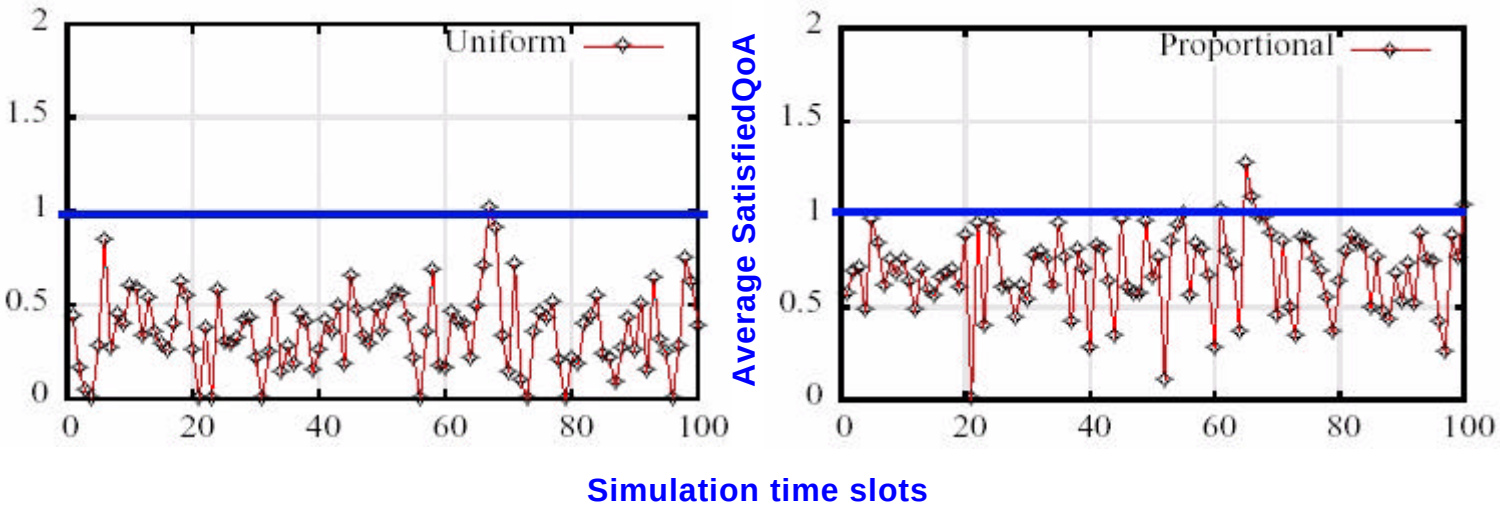
- **By increasing the replication ratio, the avg. SatisfiedQoA values are towards 1**

Effect of Initial Replica Selection on SatisfiedQoA

Experiment

- Graph(1000,3000), fixed no. replicas: 1000
- node: up_prob: 30%, req.QoA: 50-99%, link_fail: 0-10%
- proactive placement: Random, query model: Zipf

Selection strategies: Uniform versus Proportional to access counter



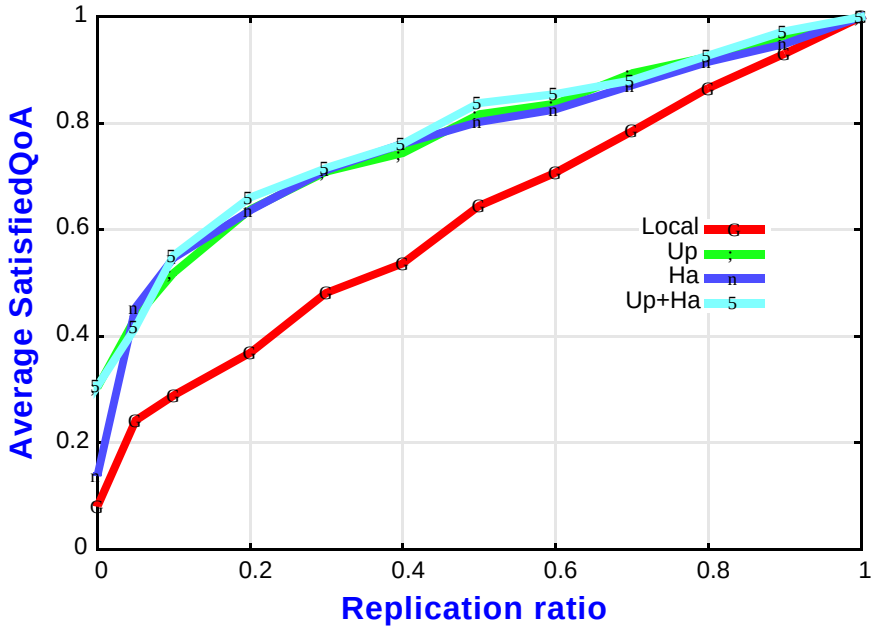
Observation

- **Proportional offers higher SatisfiedQoA than Uniform**

Effect of On-Demand Placement on SatisfiedQoA

Experiment

- Graph(1000,3000), node: up_prob: 30%, req.QoA: 50-99%, link_fail: 0-10%
- proactive placement: Random, query model: Uniform



Observation

- **The heuristics (Up, Ha, Up+Ha) offer higher SatisfiedQoA than Local**
- **The result further indicates the benefit of cooperative placement**
  - especially for P2P systems

Conclusion

Summary

- **Mechanisms to study the effectiveness of replication schemes on QoA**
  - Availability
    - QoA concept
    - Refinement: decoupled, differentiated & fine-grained availability
  - Replication for QoA
    - Replica selection and placement problems
    - Dynamic and partial replication
    - Ranking-based heuristics for improving QoA
  - Simulation
    - event-driven simulation (CNCL, Leda)
    - indicates the benefit of cooperative placement

Outlook

- **New algorithms for GuaranteedQoA**
- **Simulation model extension**
  - other network topology, e.g., Power-law topology, star, etc.
- **Service model extension**
  - Replication for streaming media

Experimental Setup

Event-Driven Simulation Model

Graph generation

Node/Link initialization

Nodes' up probability

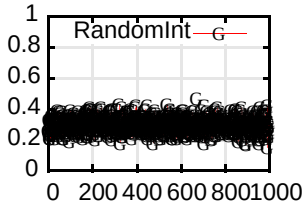
PROACTIVE PLACEMENT

#Up nodes per simulation time slot

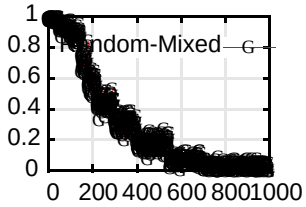
#Query event per simulaiton time slot

RandomGraph

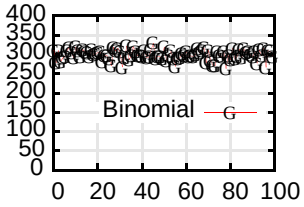
RandomInt



RandomMix

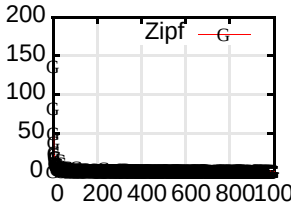


Binomial



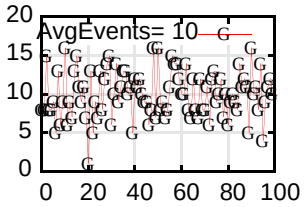
Query pattern

Zipf



Uniform

Uniform



Simulation run

ON-DEMAND PLACEMENT

Result display

Used Libraries:
Leda, CNCL