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QoS-Aware Service Selection in Geographically Distributed Clouds

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Outline

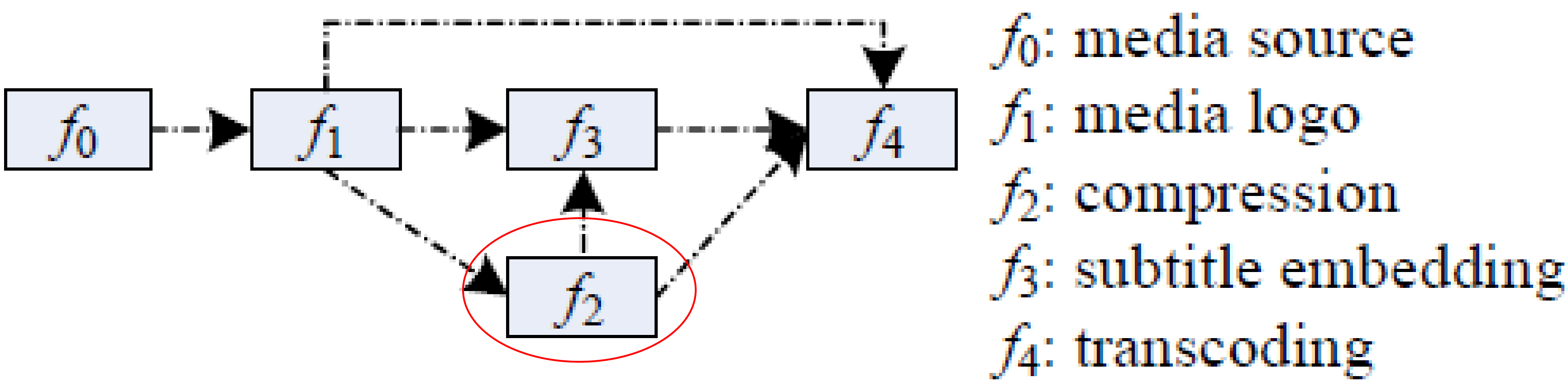
- Background and Motivation
- Problem Statement
- Our Approach
- Evaluation

Background

- Cloud service
  - More and more services are accessible with the growth of cloud computing.
  - Functional simplicity
    - It is functional limited for a single service.
    - How can we effectively utilize the plentiful services?
- Service composition
  - An effective way to utilize the plentiful services, and compensates for the simplicity of single service.

Service Composition

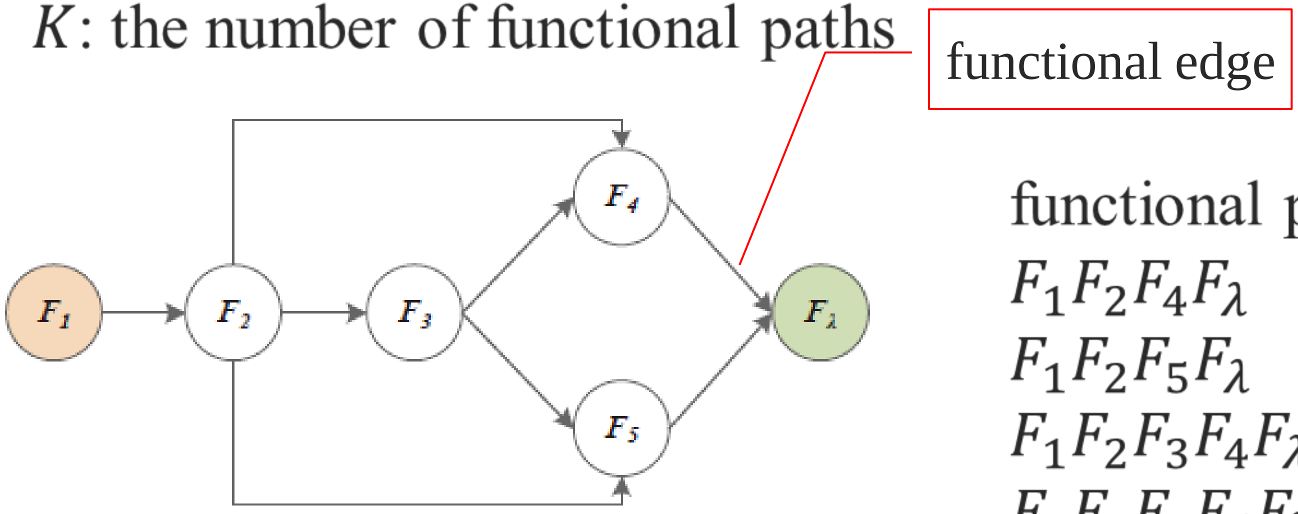
- To accomplish an integrated task, many basic processing units are composed to achieve the complicated job.
- Service (functional) component
  - The basic processing unit



An example of service composition for multimedia delivery

Functional Graph

- A functional graph is defined as $FG = < F, E, \lambda, K >$
  - F : the set of functional components
  - E: the set of functional edges between components
  - λ: the number of components
  - K: the number of functional paths



functional paths:
$F_1F_2F_4F_\lambda$
$F_1F_2F_5F_\lambda$
$F_1F_2F_3F_4F_\lambda$
$F_1F_2F_3F_5F_\lambda$

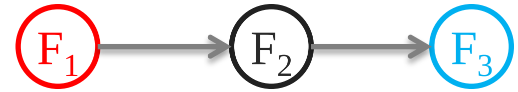
Motivation

- The opportunity
  - For service provider: rent the existing single services from various clouds, and provide some complex integrated services to users.
- The challenge
  - Functional equivalent service instances
    - Service instance: an implementation of a service component
    - Same function but different features, e.g. execution time
  - Cost limitation
  - The quality of service instances

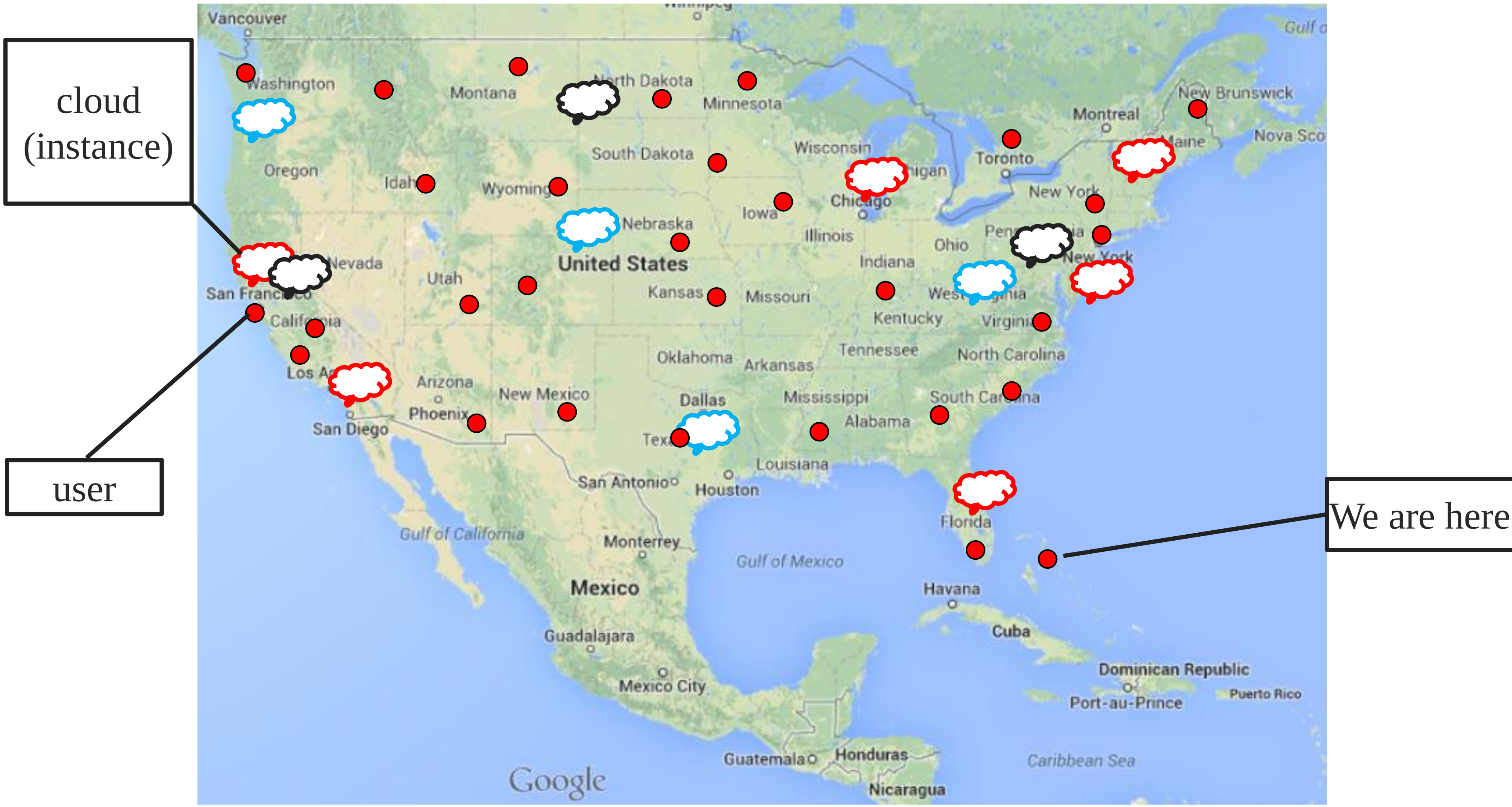
The Problem

- Problem description
  - Select a set of service instances such that the composed service offers the best quality under given functional graph.
  - An instantiation for the functional graph

The Problem

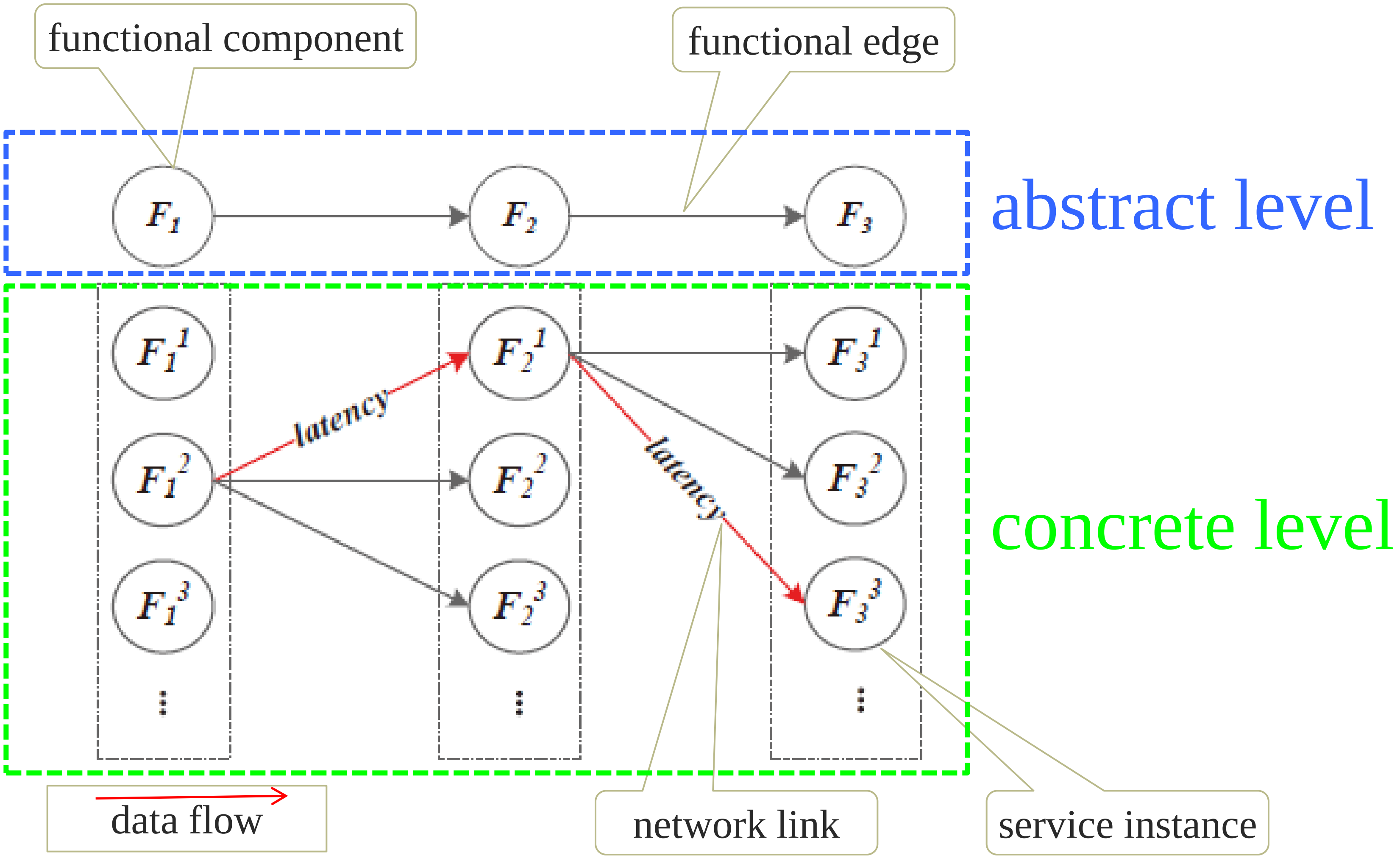


F_1
F_2
F_3



cloud (instance)
user
We are here!
Vancouver
Washington
Montana
North Dakota
Minnesota
Oregon
Idaho
Wyoming
South Dakota
Wisconsin
Michigan
Toronto
Montreal
New Brunswick
Nova Scotia
Maine
New York
Iowa
Chicago
Nebraska
Illinois
Ohio
Pennsylvania
Nevada
United States
Indiana
Utah
San Francisco
Kansas
Missouri
West Virginia
California
Kentucky
Virginia
Oklahoma
Arkansas
Tennessee
North Carolina
Los Angeles
Arizona
New Mexico
Dallas
Mississippi
South Carolina
Phoenix
Alabama
San Diego
Texas
Louisiana
San Antonio
Houston
Florida
Gulf of California
Monterrey
Gulf of Mexico
Mexico
Havana
Cuba
Guadalajara
Dominican Republic
Mexico City
Port-au-Prince
Puerto Rico
Guatemala
Honduras
Caribbean Sea
Nicaragua
Google

Instantiation of Functional Graph



Abstract Level & Concrete Level

NOTATION CONTRADISTINCTION

Abstract Level	**Concrete Level**
functional component $F_i, 0 \leq i \leq \lambda$	service instance $F_i^j, j = 1, 2, ..., \theta(i)$
functional path $P_k, 1 \leq k \leq K$	data flow ω_k
functional edge E_{ij}	network link L_{ij}

Selection function

$\boldsymbol{\pi}$ **and** $\boldsymbol{\pi}'$: $\boldsymbol{\pi(F_i) = F_i^j, \pi(E_{ij}) = L_{ij}, \pi'(\omega_k) = P_k}$

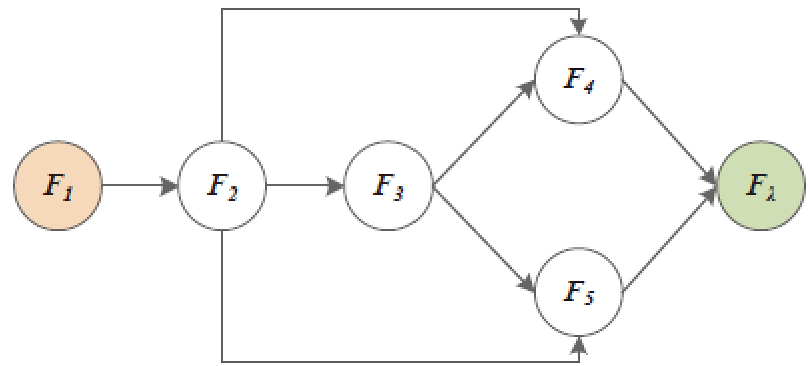
Quality of Service Instance Set

- How to judge the quality of a set of instances?
  - Quality of an instance set
  - QoS (quality of service)
    - Objective: best quality
      - The minimal expected *response time* for all *users*
    - Network model
      - How to measure the network latency between two locations?
      - Network Coordinate System (NCS)

Network Coordinate System (NCS)

- Network latency
  - It is infeasible to gather the network latency.
    - Due to the large amount of measure traffic.
  - NCS is widely used to estimate the network latency.
  - Latency varies a lot depending on the location.
  - 2-dimensional coordinate system
  - Communication latency: $c(l_1, l_2) = \alpha + \beta \cdot dist(l_1, l_2)$
    - $dist(l_1, l_2)$: Euclidean distance between the two locations l_1 and l_2.

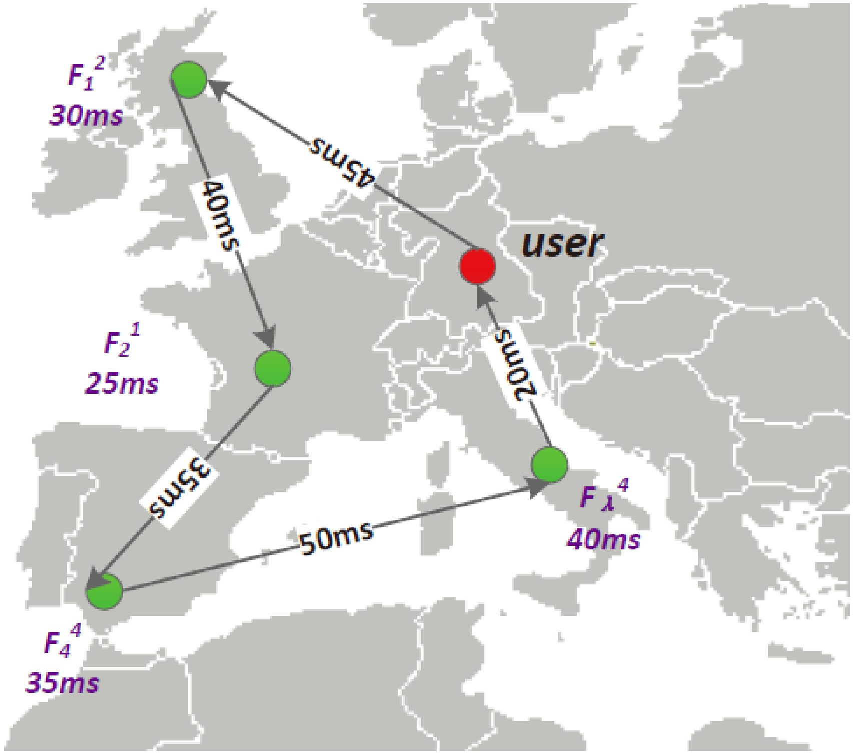
Rethink the Problem



- Objective
  - Minimize the response time
    - Network latency
    - Execution time
  - However, the response time varies
    - User location
      - For users located on different locations, the network latency varies.
    - Functional path selection
      - Given functional graph, there will be multiple functional paths, the response time varies as the path selection.
      - For some user, there is a probability distribution to determine which path will be selected, according to the context.

Delay of Data Flow

- A data flow is an instantiation of a functional path.
- The delay of a data flow consists of two parts
  - Network latency
    - For all of the network links
    - (functional edges)
  - Execution time
    - For all service instances
    - (functional component)



Case for One Data Flow

$$D(\omega) = \sum_{i=1}^{\lambda} T(F_i^{\omega}) * Z(i, \pi'(\omega)) + \sum_{i \le i,j \le \lambda} c\left(F_i^{\omega}, F_j^{\omega}\right) * Z(i, j, \pi'(\omega))$$

λ : the number of functional components for given functional graph

F_i^{ω} : the instance of component F_i in the flow ω

$T(F_i^{\omega})$: execution time of the instance F_i^{ω}

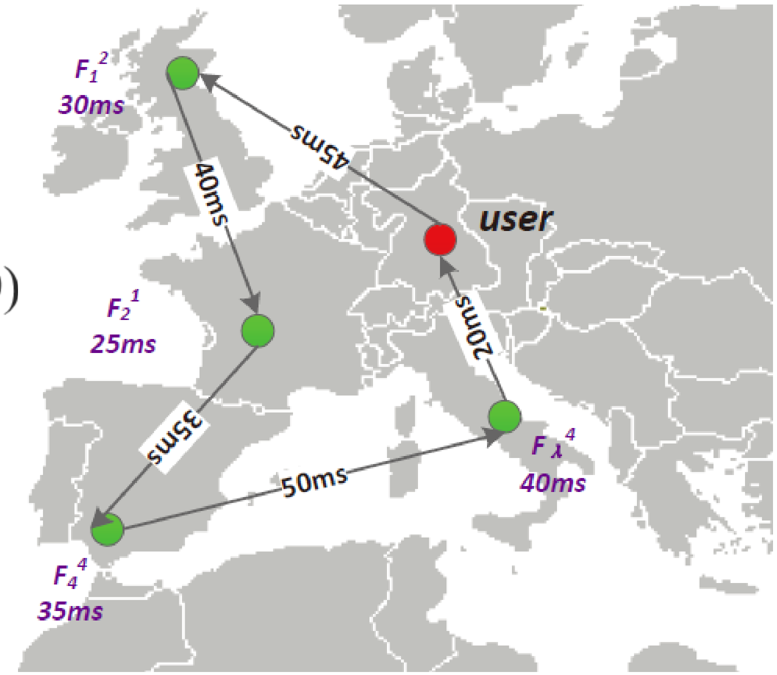
$\pi'(\omega)$: the functional path corresponds to the flow ω

$c(x, y)$: the network latency between instance x and y.

$$Z(i,k) = \begin{cases} 1, & P_k \text{ contains } F_i; \\ 0, & \text{otherwise.} \end{cases} \qquad Z(i,j,k) = \begin{cases} 1, & P_k \text{ contains } E_{ij}; \\ 0, & \text{otherwise.} \end{cases}$$

Response Time (1)

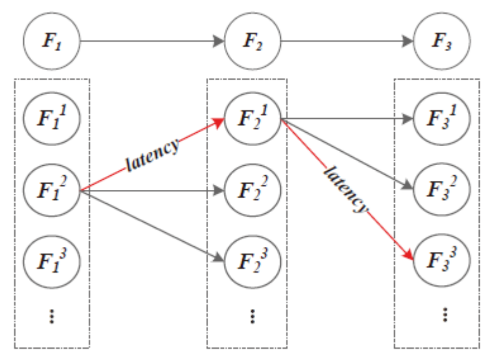
- Response time for given data flow ω and user u (user location)
  - $\boldsymbol{R(u,\omega) = D(\omega) + c(u, F_1^{\omega}) + c(F_\lambda^{\omega}, u)}$
    - Total response time for user $\boldsymbol{u}$
  - Data flow delay: 255ms
    - Network latency: (40+35+50)
    - Execution time: (30+25+35+40)
  - Response time: 320ms
    - 255+45+20



Response Time (2)

- Response time for given function path P_k and user u
  - $R(u,k) = R(u, \omega_k^{opt}) \le R\left(u, \omega_k^j\right)(1 \le j \le J_k)$
  - $\omega_k^j (1 \le j \le J_k)$: the available flows of path P_k
  - $J_k = \prod_{i=1}^{\lambda} N(F_i)^{Z(i,k)}$
  - $N(F_i)$: the number of selected instance of component F_i

The data flow with minimal delay will be selected to execute the service for given user.



Response Time (3)

- Response time (expected) for given functional graph FG and user u
  - $\boldsymbol{R(u) = \sum_{k=1}^{K} p(P_k) * R(u,k)}$
  - $\boldsymbol{p(P_k)}$: the probability of path $\boldsymbol{k}$ will be selected.
  - For given functional graph, there is an optimal set of service instances for each user. But the optimal set of each user varies.

Quality of Service Instance Set

- Response time is based on the service instances that can be selected.
  - The data flows are based on the instance set $\boldsymbol{S}$.
- The quality for given service instance set $\boldsymbol{S}$.
  - $\boldsymbol{Q}(\boldsymbol{S}) = \frac{1}{\mu}\sum_{u=1}^{\mu} \boldsymbol{R}(\boldsymbol{u})$
  - $\boldsymbol{\mu}$: the number of users
    - It can be the representative user, and reflects the user distribution.
- ***Our problem again***
  - Select a set of service instances set $\boldsymbol{S}$ such that $\boldsymbol{Q}(\boldsymbol{S})$ is minimal.

Algorithms

- Simple case
  - One instance for each functional component
- General case
  - Multiple instances for each functional component
  - Limitation for the total number of instances

Simple Case

- For given functional graph $FG =< F, E, \lambda, K >$, only one service instance could be selected for each functional component.
  - $\forall \boldsymbol{i},\ \boldsymbol{N}(\boldsymbol{F_i}) = \mathbf{1}, \sum_i \boldsymbol{N}(\boldsymbol{F_i}) = \boldsymbol{\lambda}$
- Basic idea
  - From initial component to the terminal component, the flow with the minimal latency should be selected.
    - The idea of shortest path algorithm
  - Initial component
  - Terminal component

Simple Case - Algorithm

- Initial (Terminal) component selection
  - Selected in greedy manner, according to the user distribution.
  - The facility location problem.
- Source – Destination (flow selection)
  - From initial component to terminal component
  - The shortest part problem
    - Each instance has an executing time

General Case

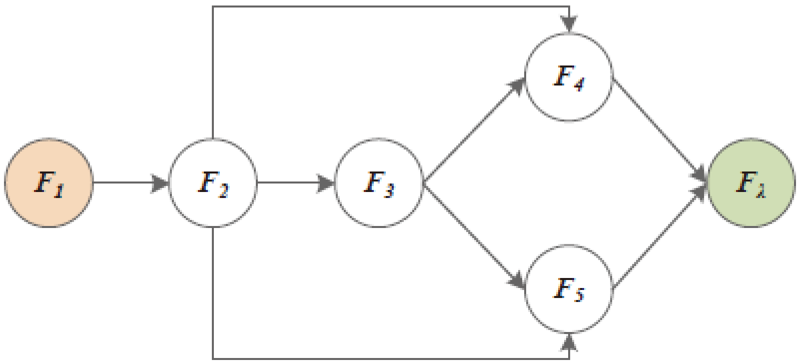
- There may be multiple service instances for each component, but the total number of instances is limited.
  - $\forall \boldsymbol{i},\ \boldsymbol{N}(\boldsymbol{F}_{\boldsymbol{i}}) \geq \mathbf{1}$
  - $\sum_{i} \boldsymbol{N}(\boldsymbol{F}_{\boldsymbol{i}}) \leq \boldsymbol{\gamma}$
  - For the users, it is more likely to achieve the optimal instance set for her, since more service instances can be selected.
  - Cost limitation
    - The service provider cannot rent too many instances.

General Case - Algorithm

- Basic idea
  - Vote
    - For each user, there is a instance set, that best satisfies the user.
    - Each user declares her preference for the service selection.
    - For each service instance, each user marks a *score* for it.
    - The *score* is based on shortest path selection.
  - Select
    - For each component, the instance with the highest *score* will be selected.
    - Then, other instances are sorted in descending order, and select the first $\gamma - \lambda$ instances.

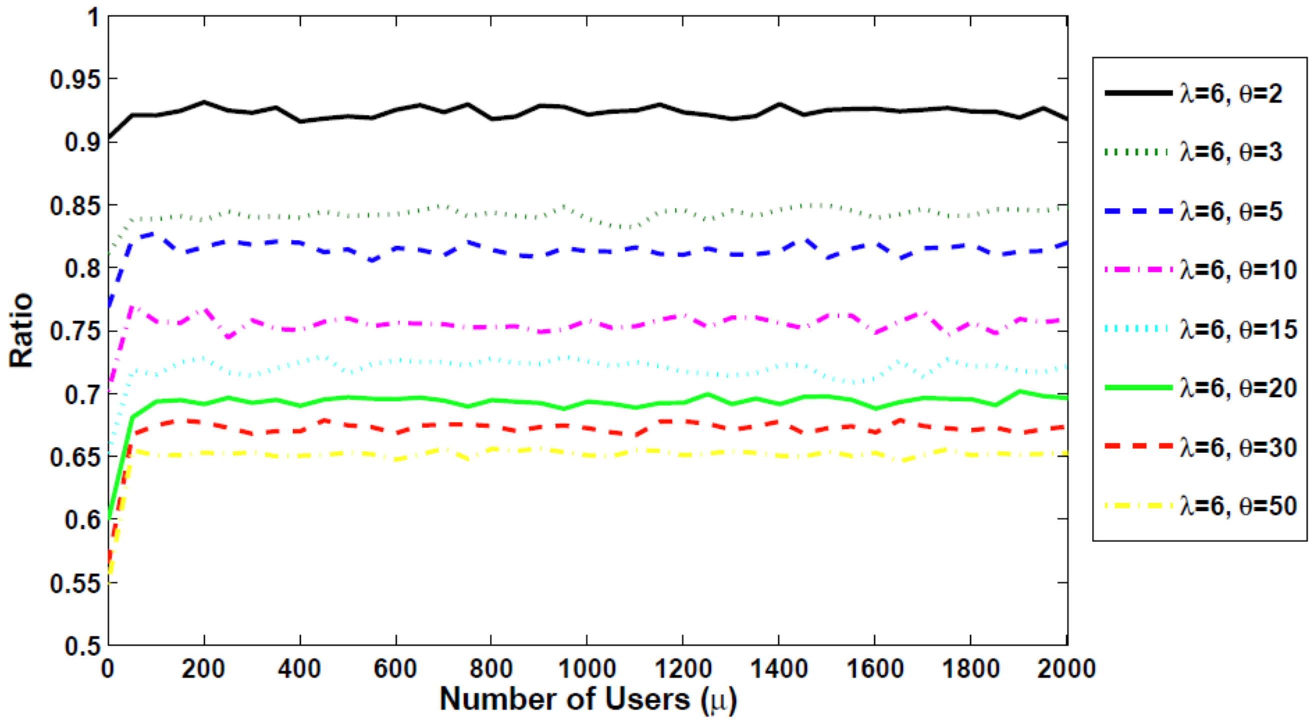
Evaluation – Simulation Setup

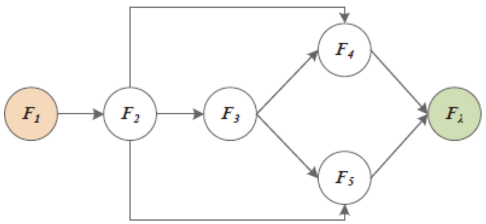
- Settings
  - Function graph
    - Random probability
  - NCS
    - $\alpha = 1, \beta = 50$
  - User/Instance location
    - Two-dimensional coordinate space: $[0,1] \times [0,1]$
  - The number of candidate instances ($\boldsymbol{\theta}$) is the same for all functional components.
  - Baseline
    - Random algorithm



Result – Simple Case

- Impact of μ



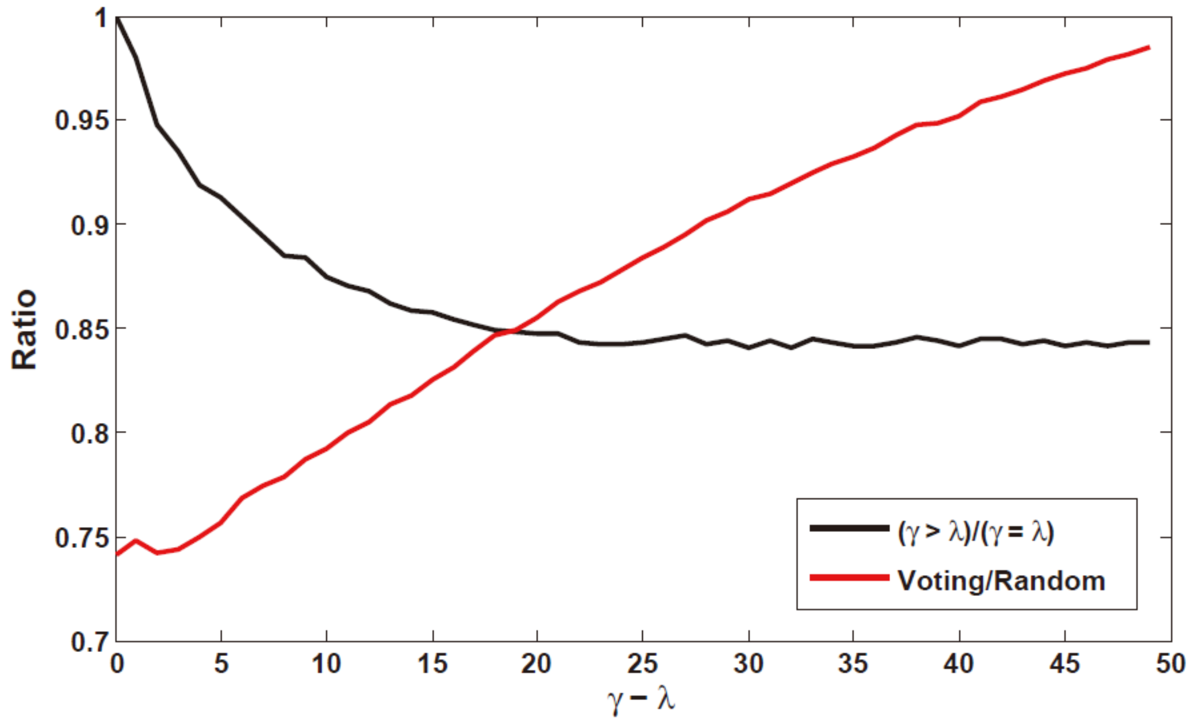


✓ Impact of θ.
✓ Case when $\mu = 1$.
✓ Case when $\theta = 2$.
✓ Impact of μ.

Result – General Case

- Impact of γ

More selected instanced provides better quality (less delay). But, when $\gamma - \lambda$ comes to some threshold, the ratio tends to be steady, because the service instances with high *score* have yet to be selected. The new selected are useless in improve the quality.



The voting algorithm and the random algorithm have the same result, when all instances are selected. (red line)

Conclusion

- Service selection
  - A set of service instances with guaranteed quality.
- Quality of selected instances
  - Network latency
  - Data flow delay
  - Response time
- Algorithm
  - Simple case
  - General case

Thanks!

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