Hybrid Computing Resource Collaboration Combing Cloud and Fog with Software Defined Networking

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Outline

1. What is hybrid computing?
2. IT Infrastructure for hybrid computing
3. Networking issues for hybrid computing
4. Potential solution with SDN

How is the weather today?

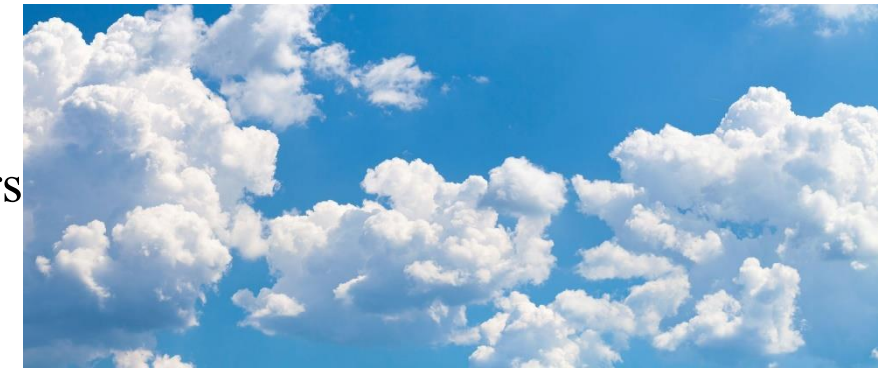
Cloud is made of water drops or ice crystals floating **in the sky**, comprising a visible mass of liquid drops or frozen crystals made of water or various chemicals [1].

Fog is a visible mass consisting of cloud water drops or ice crystals suspended in the air **at or near the Earth's surface** [2].

[1] https://en.wikipedia.org/wiki/Cloud [2] https://en.wikipedia.org/wiki/Fog

Cloud computing and fog computing

Cloud computing is a kind of Internet-based computing that provides shared processing resources and data to computers and other devices on demand [3].



Fog computing is an architecture that uses end-user clients or near-user edge devices to carry out a substantial amount of storage, communication, and control, configuration, measurement [4].

[3] https://en.wikipedia.org/wiki/Cloud_computing [4] https://en.wikipedia.org/wiki/Fog_computing

Different flavors of fog computing

- **Fog computing** is considered as an extension of the cloud computing paradigm from the core of network to the edge of the network. It is a highly virtualized platform that provides computation, storage, and networking services between end devices and traditional cloud servers [5]. ——from cisco view.

- **Fog computing** is a scenario where a huge number of heterogeneous (wireless and sometimes autonomous) ubiquitous and de-centralized devices communicate and potentially cooperate among them and with the network to perform storage and processing tasks without the intervention of third parties. These tasks can be for supporting basic network functions or new services and applications that run in a sandboxed environment. Users leasing part of their devices to host these services get incentives for doing so [6]. ——from HP Lab's view.

[5] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, "Fog computing and its role in the internet of things," in Proceedings of the First Edition of the MCC Workshop on Mobile Cloud Computing, ser. MCC'12. ACM, 2012, pp. 13–16.
[6] L. M. Vaquero and L. Rodero-Merino, "Finding your way in the fog: Towards a comprehensive definition of fog computing," ACM SIGCOMM Computer Communication Review, 2014.

Some similar concepts

- **Edge computing** is similar with fogging, pushing the frontier of computing applications, data, and services away from centralized nodes to the logical extremes of a network [5].

- **Mobile cloud computing (MCC)** refers to an infrastructure in which both the data storage and the data processing happen outside of the mobile devices [6].

- **Mobile edge computing (MEC)** can be seen as a cloud server running at the edge of a mobile network and performing specific tasks that could not be accomplished with traditional network infrastructure[7].

[5] Garcia Lopez, et al., "Edge-centric Computing: Vision and Challenges". SIGCOMM Comput. Commun. Rev. 45 (5): 37–42, Sep. 2015.
[6] H. T. Dinh, et al., "A survey of mobile cloud computing: architecture, applications, and approaches," WCMC, 2013.
[7] ETSI. Mobile-edge computing. http://goo.gl/7NwTLE, 2014.

Characters of fog computing

- Edge location, location awareness, and low latency.
- Geographical distribution.
- Supporting large-scale sensor networks.
- Support for mobility.
- Real-time interactions.
- Predominance of wireless access.
- Interoperability and federation.
- Support for on-line analytic and interplay with the Cloud.

[5] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, “Fog computing and its role in the internet of things,” in Proceedings of the First Edition of the MCC Workshop on Mobile Cloud Computing, ser. MCC’12. ACM, 2012, pp. 13–16.

Comparison between cloud and fog computing

	Cloud	Fog
Latency	High (eventual consistency)	Low (locality)
Access	Fixed and wireless	Mainly wireless
Explicit mobility	NA	Lispmob[8]
Control	Centralised/hierarchical (full control)	distributed/hierarchical (partial control)
Service access	through core	at the edge/ on handheld device
Availability	99.99%	Highly volatile/ highly redundant
# of users/devices	Tens/Hundreds of millions	Tens of billions
Price per server device	$1500-3000	$50-200
Main content generator	Humans	Devices/sensors
Content generation	Central location	Anywhere
Content consumption	End devices	Anywhere
Software virtual infrastructure	Central corporate servers	User devices

From HP Lab [6]

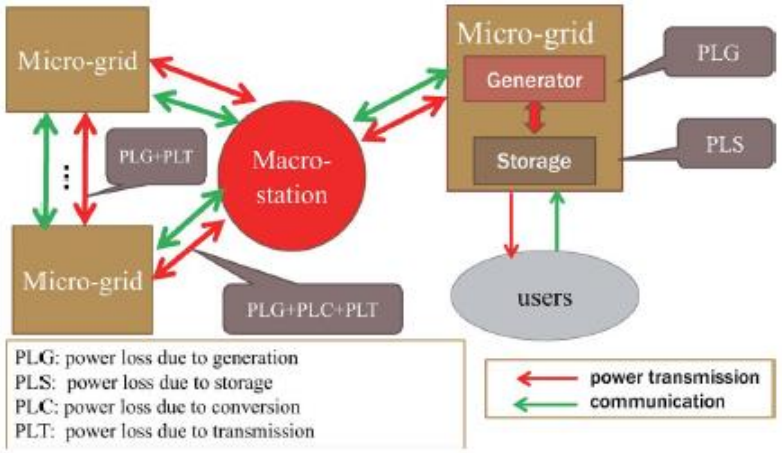
8: LISPmob is an open-source LISP Mobile Node implementation for Linux. With LISPmob, hosts can change their network attachment point without losing connectivity, while maintaining the same IP address. - See more at: http://networks.cttc.es/mobile-networks/software-tools/lispmob/#sthash.TsdcpOAz.dpuf

[6] L. M. Vaquero and L. Rodero-Merino, “Finding your way in the fog: Towards a comprehensive definition of fog computing,” ACM SIGCOMM Computer Communication Review, 2014.

Application scenarios of fog computing

Smart Grid: Energy load balancing applications may run on network edge devices, such as smart meters and micro-grids. Based on energy demand, availability and the lowest price, these devices automatically switch to alternative energies like solar and wind.

Fog computing in smart grid [8]

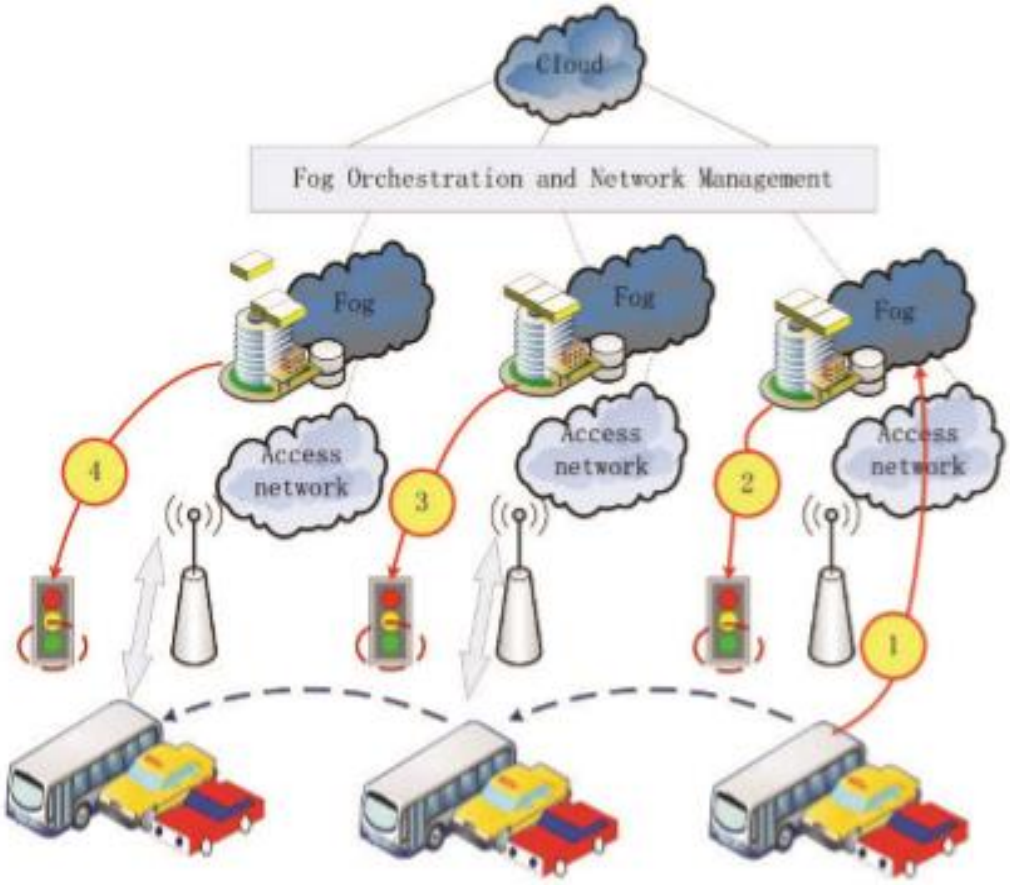


Micro-grids based power delivery system and different types of power losses that affect it [9]

[8] Ivan Stojmenovic, Sheng Wen, The Fog Computing Paradigm: Scenarios and Security Issues, Proceedings of the 2014 Federated Conference on Computer Science and Information Systems pp. 1–8.
[9] C. Wei, Z. Fadlullah, N. Kato, and I. Stojmenovic, "On optimally reducing power loss in micro-grids with power storage devices," IEEE Journal of Selected Areas in Communications, 2014.

Application scenarios of fog computing

Smart Traffic Lights and Connected Vehicles: Video camera that senses an ambulance flashing lights can automatically change street lights to open lanes for the vehicle to pass through traffic. Smart street lights interact locally with sensors and detect presence of pedestrian and bikers, and measure the distance and speed of approaching vehicles.



Fog computing in smart traffic lights and connected vehicles [8]

[8] Ivan Stojmenovic, Sheng Wen, The Fog Computing Paradigm: Scenarios and Security Issues, Proceedings of the 2014 Federated Conference on Computer Science and Information Systems pp. 1–8.

Application scenarios of fog computing

- **Wireless Sensor and Actuator Networks:** actuators serving as Fog devices can control the measurement process itself, the stability and the oscillatory behaviours by creating a closed-loop system.
- **Decentralized Smart Building Control:** information can be exchanged among all sensors in a floor, and their readings can be combined to form reliable measurements.
- **IoT and Cyber-physical systems (CPSs):** Fog computing in this scenario is built on the concepts of embedded systems in which software programs and computers are embedded in devices for reasons other than computation alone.
- **Software Defined Networks (SDN):** Fog computing framework can be applied to implement the SDN concept for vehicular networks.
- **Augmented reality (AR) and real-time video analytics**: AR system supported by fog computing can maximize throughput and reduce latency in both processing and transmission.
- **Content delivery and caching**: The fog server can provide dynamic customizable optimization based on client devices and local network conditions.
- **Mobile big data analytics:** A federation of fog and cloud can handle the big data acquisition, aggregation and preprocessing, reducing the data transportation and storage, balancing computation power on data processing.

[10] Shanhe Yi, et al., “A Survey of Fog Computing: Concepts, Applications and Issues,” Mobidata’15, Hangzhou, China, Jun. 2015.

Issues of fog computing

- **Fog networking:** how to connect every component of the fog at large scale, such as IoT? SDN and NFV. However, cooperation between different controllers and placement of controller are issues. Also how to achieve efficient instantiation, placement and migration of virtual appliances in a dynamic network , together to meet low latency and high throughput requirements.
- **Qualify of Service (QoS):** connectivity, reliability, capacity, and delay.
- **Interfacing and programming model:** unified interface and programming model for diverse networks consisting fog nodes with dynamic mobility.
- **Computation Offloading:** which granularity to choose for offloading at different hierarchy of fog and cloud; how to dynamically partition application to offload on fog and cloud; and how to make offloading decisions to adapt dynamic changes in network, fog devices, and resources etc.
- **Accounting, billing and monitoring**: business model for Internet service provider, cloud service providers, and users.
- **Provisioning and resource management**: application-aware provisioning, resource discovery and sharing.
- **Security and Privacy:** authentication, access control, intrusion detection.

[10] Shanhe Yi, et al., "A Survey of Fog Computing: Concepts, Applications and Issues," Mobidata'15, Hangzhou, China, Jun. 2015.

Issues of fog computing

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IMPORTANT DATES

- **Manuscript Submission:** September 1, 2016
- **Decision Notification:** November 15, 2016
- **Final Manuscript Due:** January 15, 2017
- **Publication Date:** April 2017

What is hybrid computing?

Hybrid computing is the computing model combing cloud and fog computing, by exploiting various computing, storage, and network resources, such as cloud datacenters, edge datacenters, and micro-datacenters.

Notes: *edge data centers are facilities that quite literally extend the "edge" of the internet further from the traditional internet hubs in places like New York, Northern Virginia, Dallas, or Silicon Valley. Examples of companies that describe themselves as edge data center providers include EdgeConneX, vXchnge, and 365 Data Centers. That EdgeConneX went from zero data centers two years ago to two dozen today and growing.*

http://www.datacenterknowledge.com/archives/2015/08/26/how-edge-data-center-providers-are-changing-the-internets-geography/

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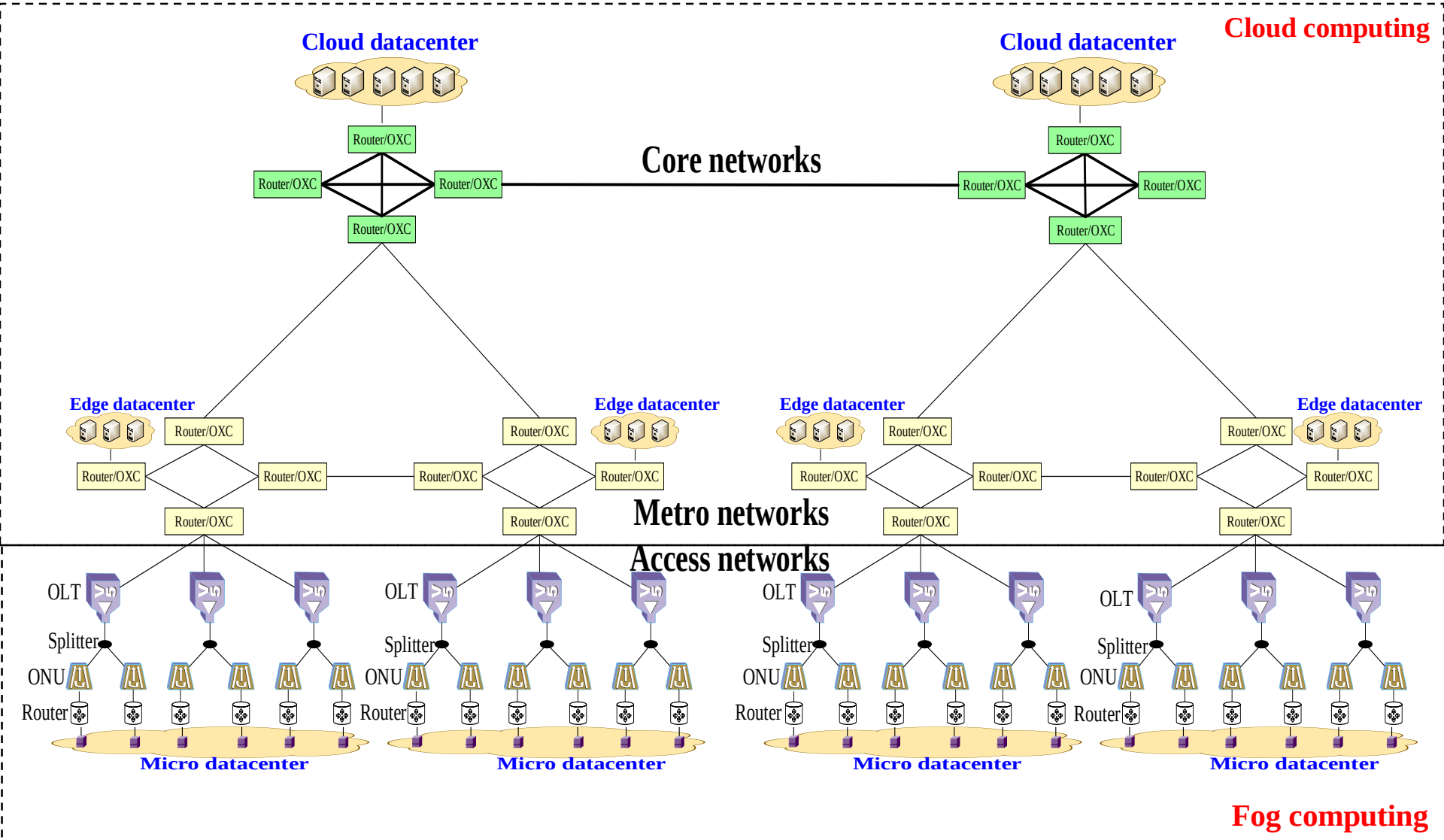
IT Infrastructure for hybrid computing



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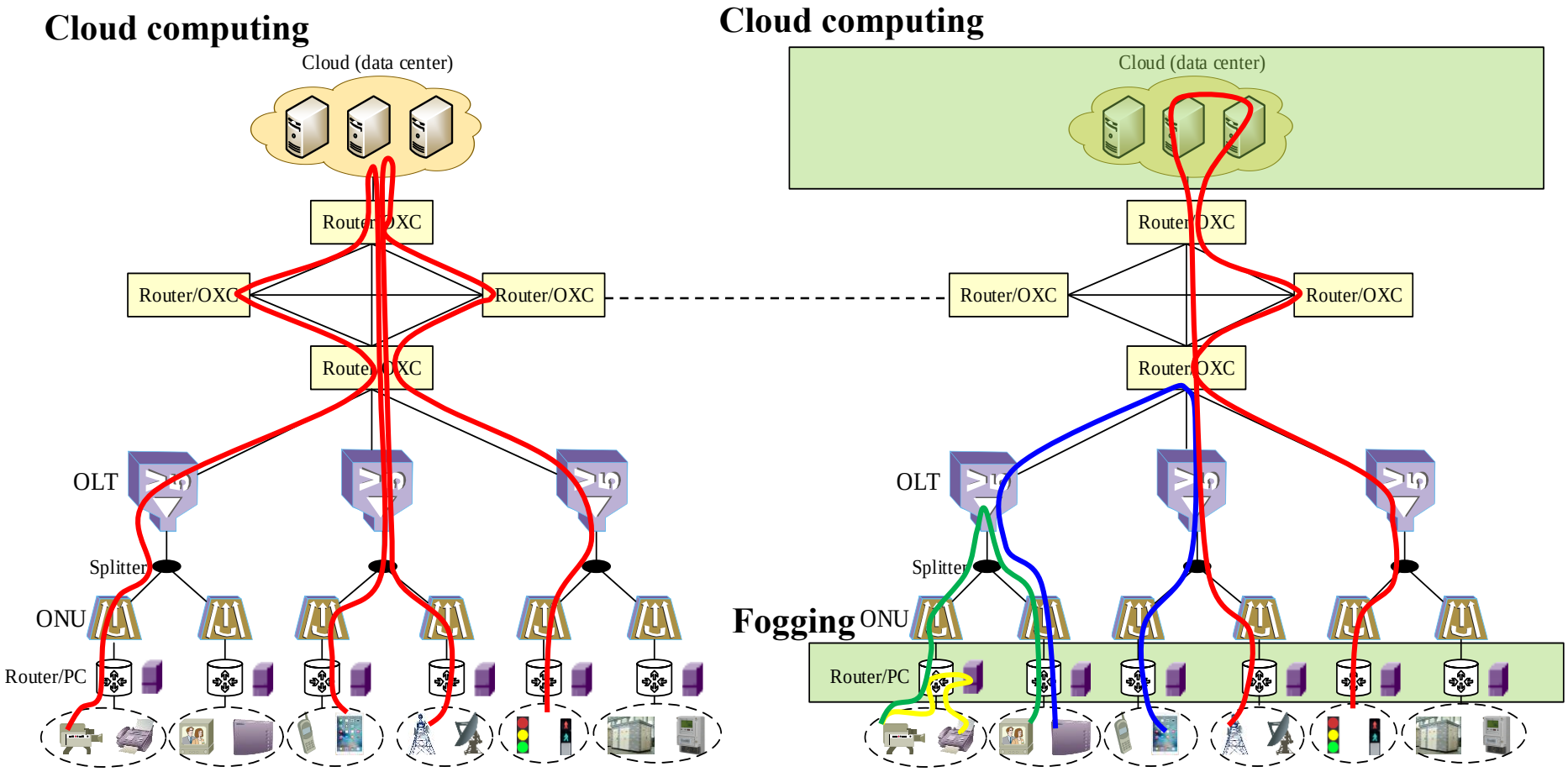
Traffic map in hybrid computing



The first tier is local processing, the second and third tiers are data processing in fogging bypass metro network, and the fourth tier is data processing in cloud.

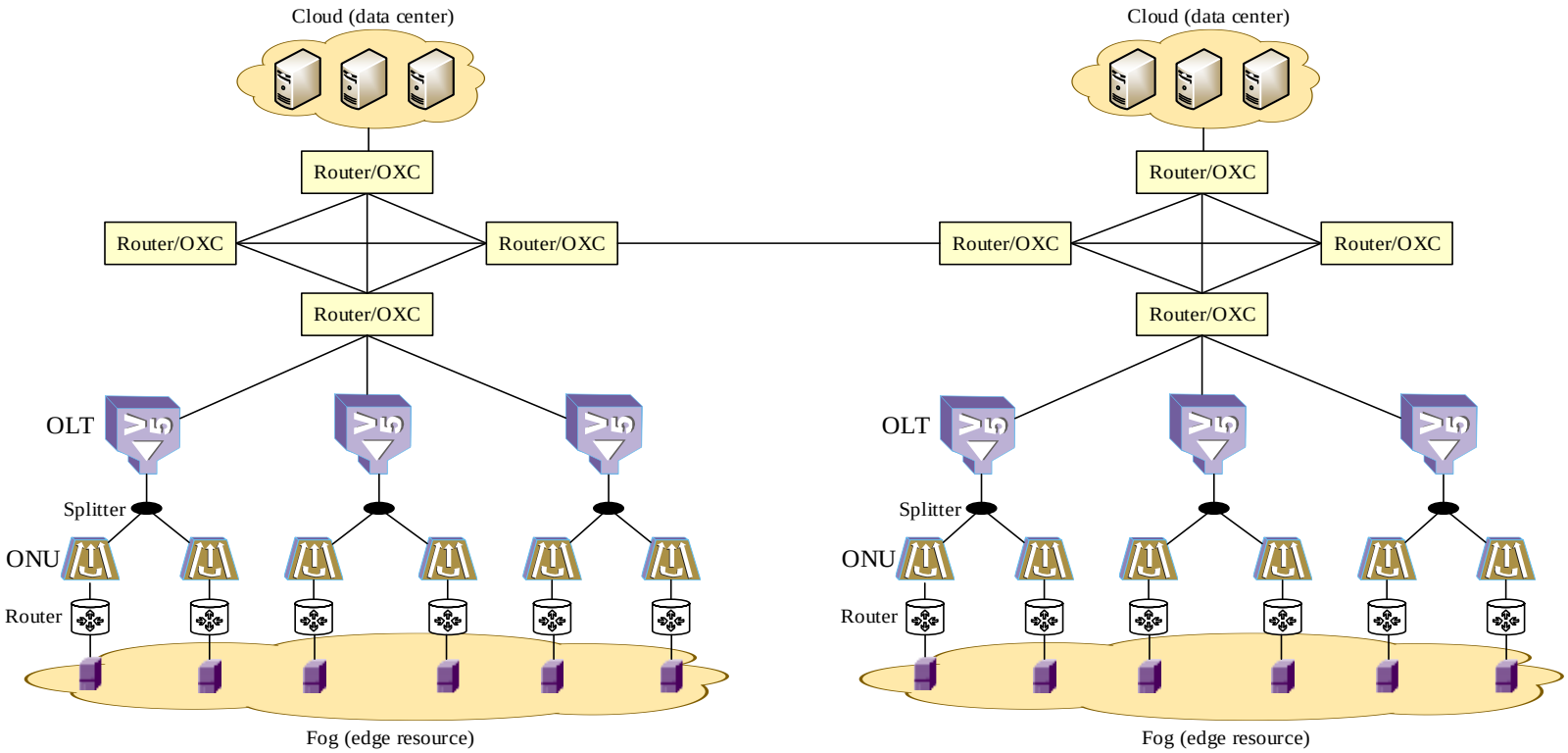
Problem description

- How to deploy IT resources for hybrid computing combining cloud and fog with optical interconnect? (*static problem*)
  The position and the volume.

- How to designate the suitable virtual machine for different requests with different requirements? (*dynamic problem*)
  Object: latency, volume,
  Constraints: datacenter resource status, power consumption, network bandwidth, and so on.

- How to build the computing resource pool at the network edge?
  Virtualization and migration implementation at the network edge

Problem description-IT resource deployment



In the scenario, it is assumed that there are only one datacenter, and each IT resource unit can only serve the area that it covers. Each IT resource unit equals to the bandwidth request 100Mbps. The capacity of unlink and downlink between OLT and ONU is assumed to be same. The ITRD optimization problem is formulated below.

Given: Network topology (only considering access networks and metro networks consisting of PON and ROADM with routers), link capacity, link length, port number, share ratio for each tier, users' traffic demands for IT resource units, IT resource unit deployment cost for different position.

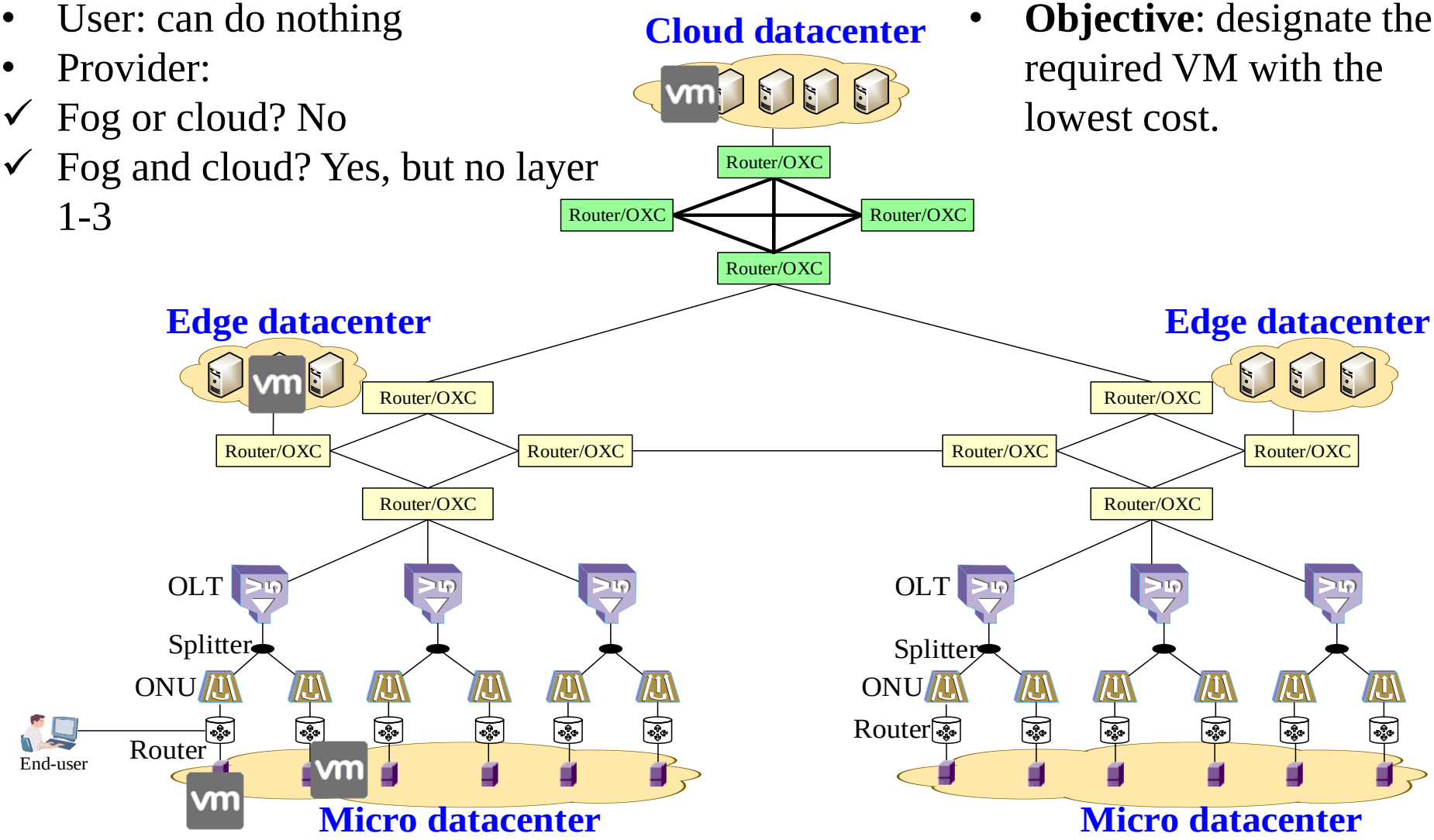
Output: How many IT resource units deployed at different tiers.

Objective: Minimize the number of IT resource units deployed.

Problem description-VM designation

- User: can do nothing
- Provider:
- ✓ Fog or cloud? No
- ✓ Fog and cloud? Yes, but no layer 1-3

- **Objective**: designate the required VM with the lowest cost.



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Why SDN or SDON?

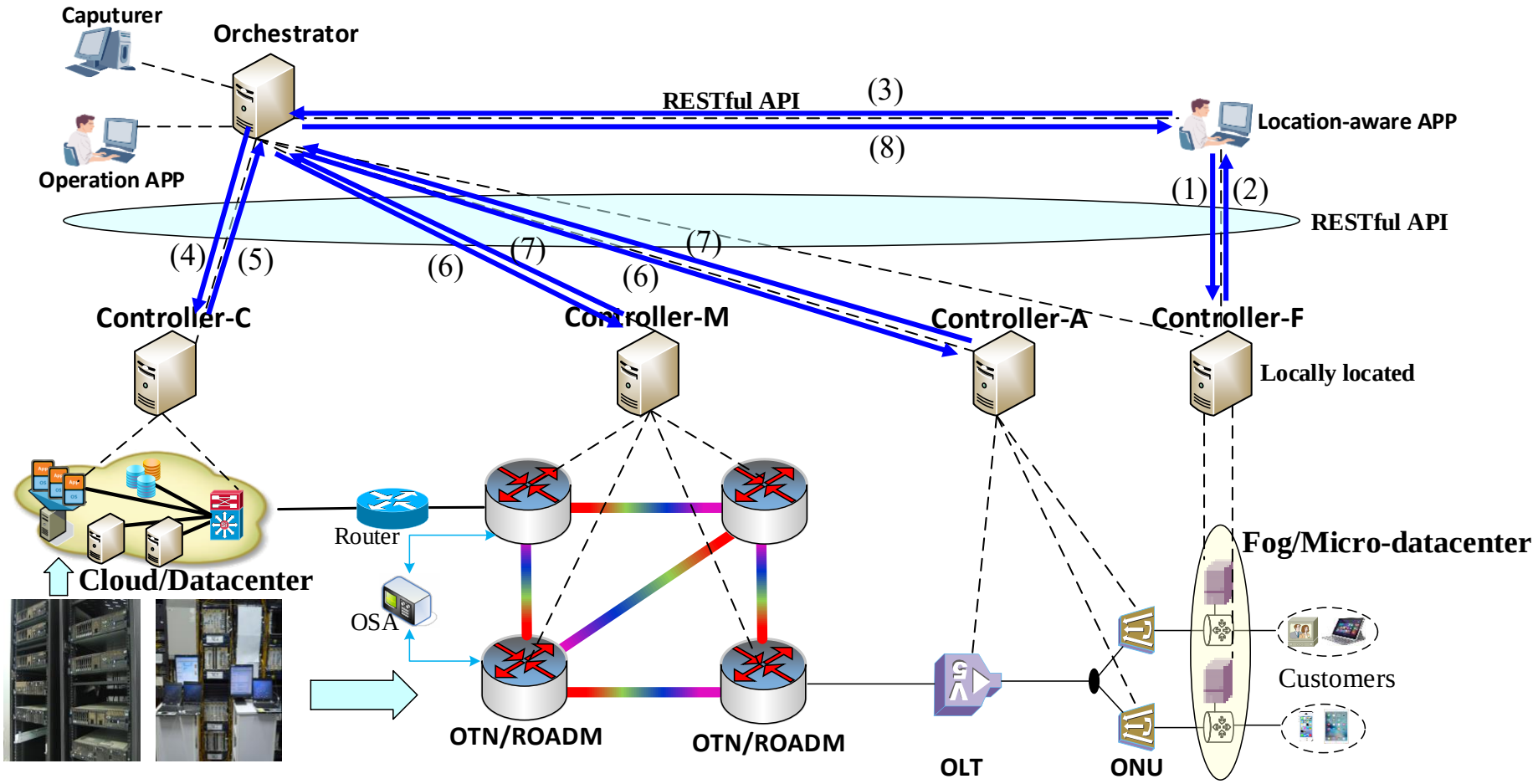
- Computing resources in hybrid computing scenario are connected with heterogeneous networks, i.e. access network, metro network, and core network, multi-stratum resources have to be considered together.

- Software defined networking (SDN) is the inevitable technology candidate due to the powerful coverage over OSI layer 1-7.

- While software defined optical networking (SDON) can provide huge bandwidth resource with low power consumption [11].

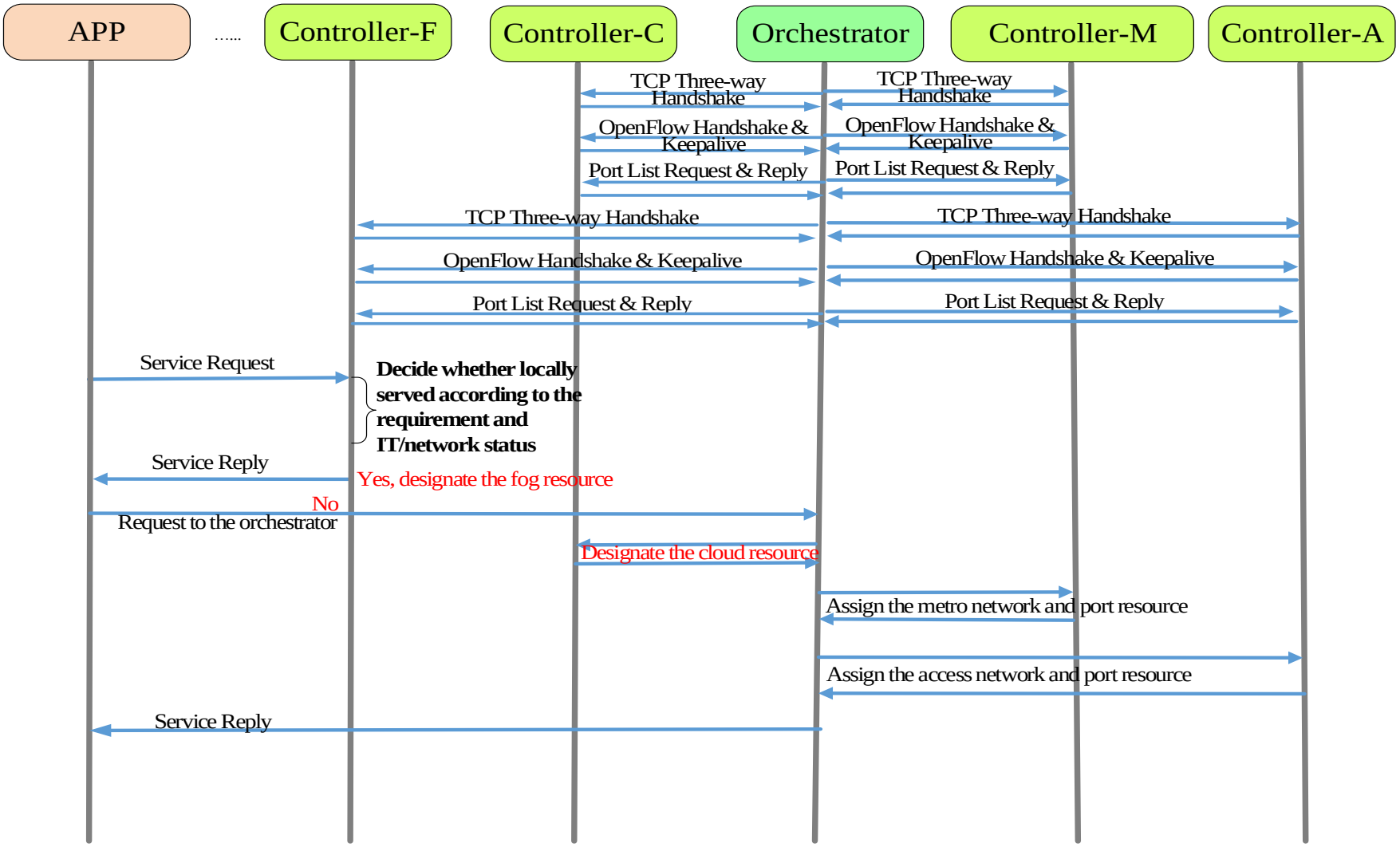
[11] Mayur Channegowda, et al., "Software-Defined Optical Networks Technology and Infrastructure: Enabling Software-Defined Optical Network Operations," Journal of Optical Communications and Networking, vol.5, no.10, pp. A274-A282, Oct. 2013.

Hierarchical control architecture for hybrid computing resource collaboration



Location-aware computing resource designation scheme: latency is the objective.

Procedure


APP
.....
Controller-F
Controller-C
Orchestrator
Controller-M
Controller-A
TCP Three-way Handshake
TCP Three-way Handshake
OpenFlow Handshake & Keepalive
OpenFlow Handshake & Keepalive
Port List Request & Reply
Port List Request & Reply
TCP Three-way Handshake
TCP Three-way Handshake
OpenFlow Handshake & Keepalive
OpenFlow Handshake & Keepalive
Port List Request & Reply
Port List Request & Reply
Service Request
Decide whether locally served according to the requirement and IT/network status
Service Reply
Yes, designate the fog resource
No
Request to the orchestrator
Designate the cloud resource
Assign the metro network and port resource
Assign the access network and port resource
Service Reply

Thank you!

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