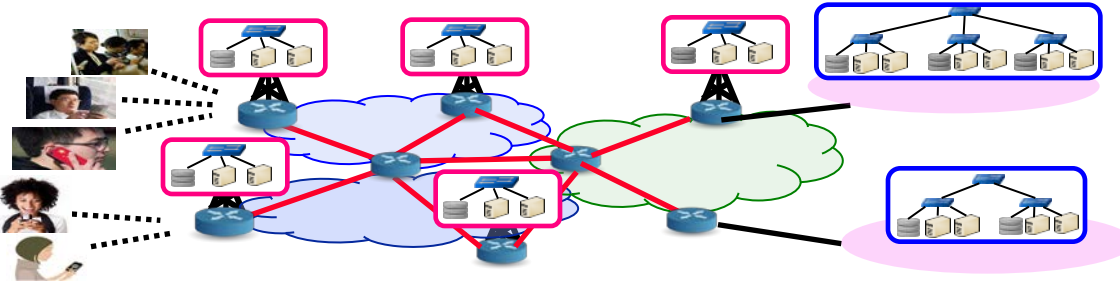


Seven Trends Leading to Opportunities in Multi-Cloud Global Application Delivery



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Dubai, November 19, 2016.

These slides and recording of this talk are available on-line at:

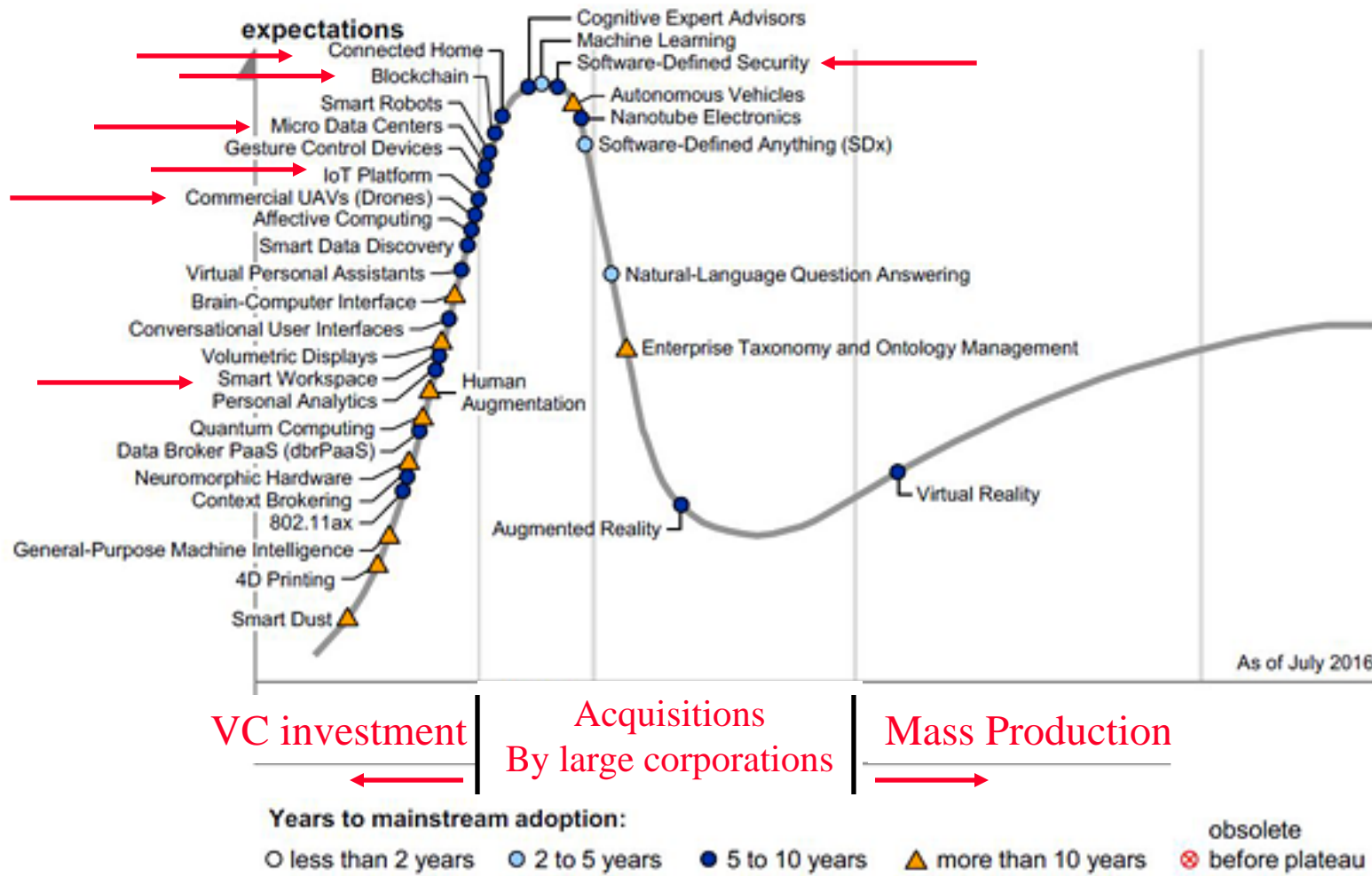
<http://www.cse.wustl.edu/~jain/talks/ccisp16.htm>

[or http://bit.ly/jain_ccisp16](http://bit.ly/jain_ccisp16)



- ❑ Why Multi-Cloud?
 - 1. Micro-Cloud Computing
 - 2. Software Defined Networking (SDN)
 - 3. Smart Everything
 - 4. Network Function Virtualization (NFV)
 - 5. Any Function Virtualization (FV)
 - 6. Mobile Edge Computing
 - 7. Micro-Services
- ❑ OpenADN Multi-Cloud Management
- ❑ Service Function Placement Problem

Gartner Hype Cycle 2016



Ref: Gartner, "Hype Cycle for Emerging Technologies, 2016," July 2016, [subscribers only], gartner.com/document/3383817

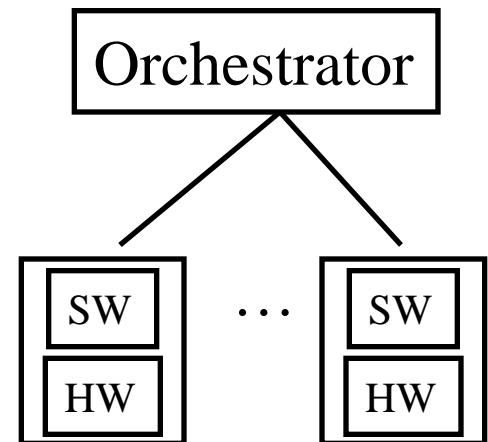
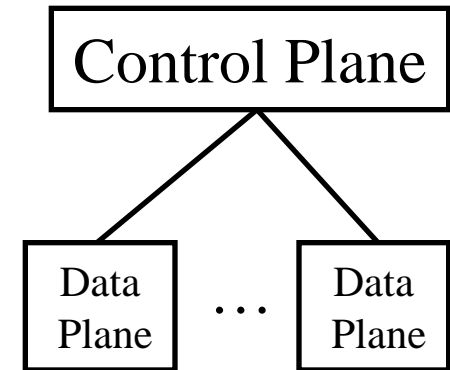
Trend 1: Micro-Cloud Computing

- ❑ Cloud computing was invented in 2006
- ❑ Then: Cloud = Large Data Center
Multiple VMs managed by a cloud management system (OpenStack)
- ❑ Today: Cloud = Computing using virtual resources
 - μ Cloud = Cloud in a server with multiple VMs.
 - Each VM with Multiple Containers \Rightarrow Multiple Services



2. Software Defined Networking (SDN)

- ❑ SDN was invented in 2009
- ❑ Then: SDN:
 - OpenFlow Southbound
 - Separation of control and data planes
 - Centralization of Control
- ❑ Now: SDN = **Disaggregation** of hw/sw
 - Commodity hardware
 - Software that runs on commodity hw
 - Open Source Software
 - ⇒ Service industry
 - Controller replaced by Orchestrator



3. Smart Everything

- ❑ What's Smart?
 - Old: Smart = Can think fast \Rightarrow High compute power
 - Then: Smart = Can remember everything \Rightarrow High storage
 - Now: Smart = Can communicate \Rightarrow Good Networking
- ❑ Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, ...



Think



Communicate



Not-Smart

Smart

IoT is a Cloud Data (\$) Mine

- ❑ Most of the revenue in IoT is not in devices but in Data
- ❑ All IoT devices come with their own cloud
 - Google Cloud, Apple Cloud, Microsoft Cloud, ...



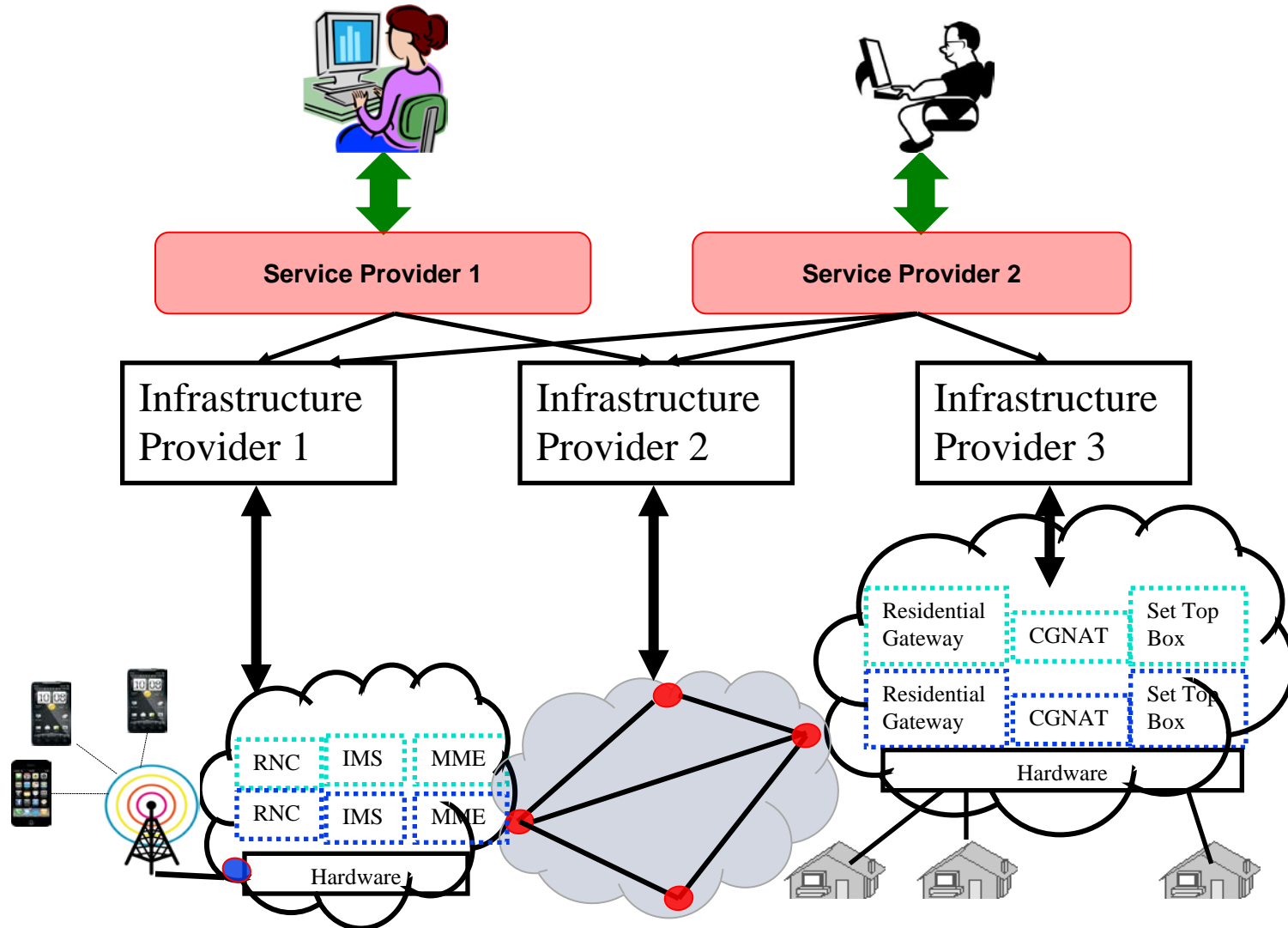
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Ref: <https://www.pinterest.com/iofficecorp/humor/>

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4. Network Function Virtualization (NFV)



Ref: Raj Jain and Subharthi Paul, "Network Virtualization and Software Defined Networking for Cloud Computing - A Survey," IEEE Communications Magazine, Nov 2013, pp. 24-31, http://www.cse.wustl.edu/~jain/papers/net_virt.htm

5. Any Function Virtualization (FV)

- ❑ “Network” function virtualization of interest to Network service providers
- ❑ But the same concept can be used by any other industry, e.g., financial industry, banks, stock brokers, retailers, mobile games, ...
- ❑ Everyone can benefit from:
 - Functional decomposition of there industry
 - Virtualization of those functions
 - Service chaining those virtual functions (VFs) or **Apps**

Networking App Market: Lower CapEx

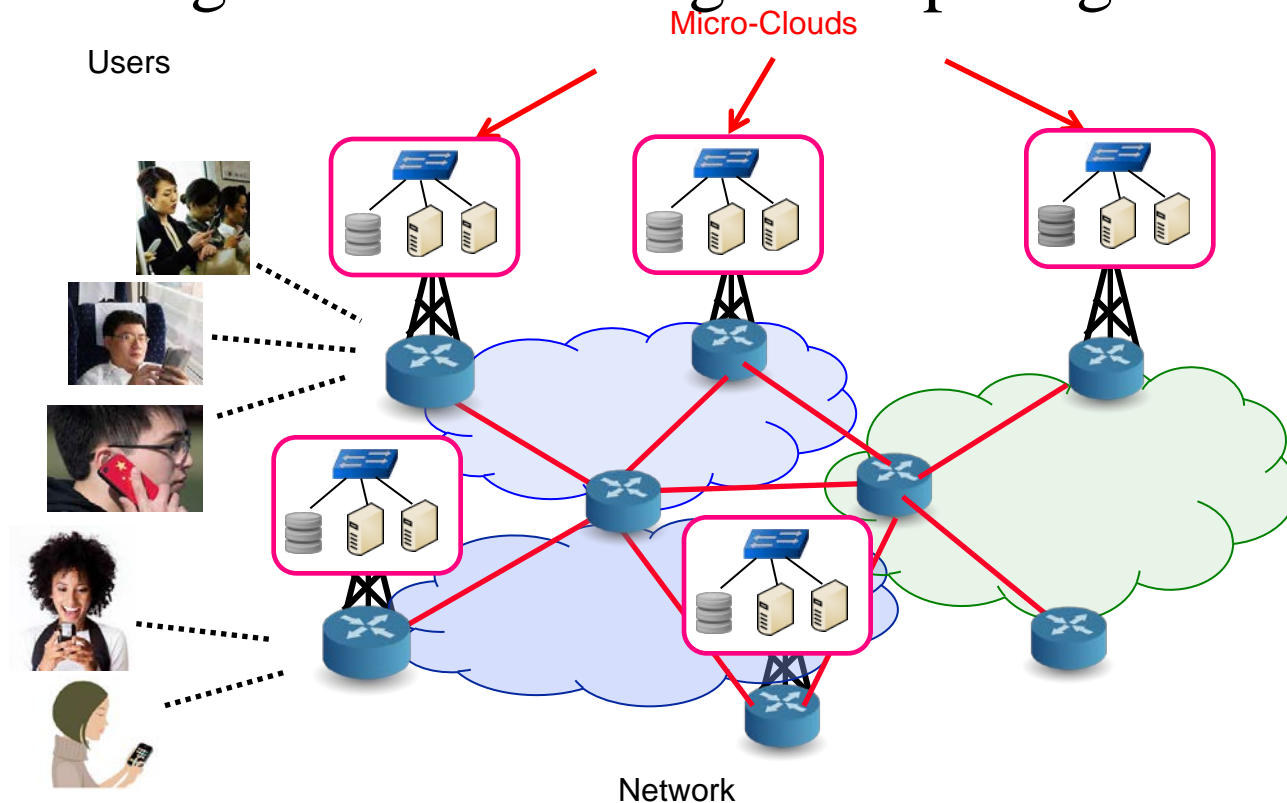
Virtual IP
Multimedia
System

Available on the
App Store



6. Mobile Edge Computing

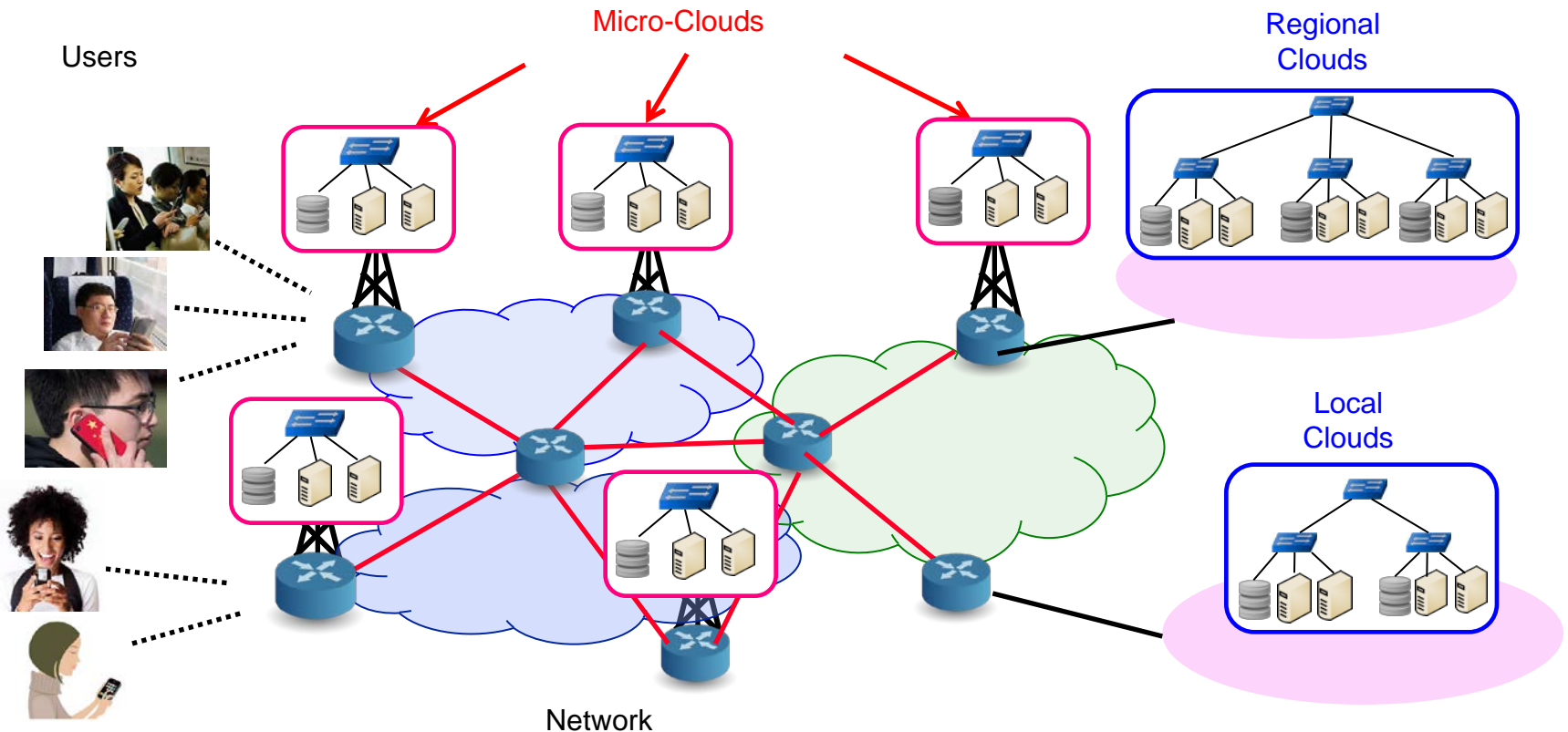
- To service mobile users/IoT, the computation needs to come to edge \Rightarrow Mobile Edge Computing



Ref: Lav Gupta, Raj Jain, H. Anthony Chan, "Mobile Edge Computing - an important ingredient of 5G Networks," IEEE Softwarization Newsletter, March 2016, <http://www.cse.wustl.edu/~jain/papers/mec16.htm>

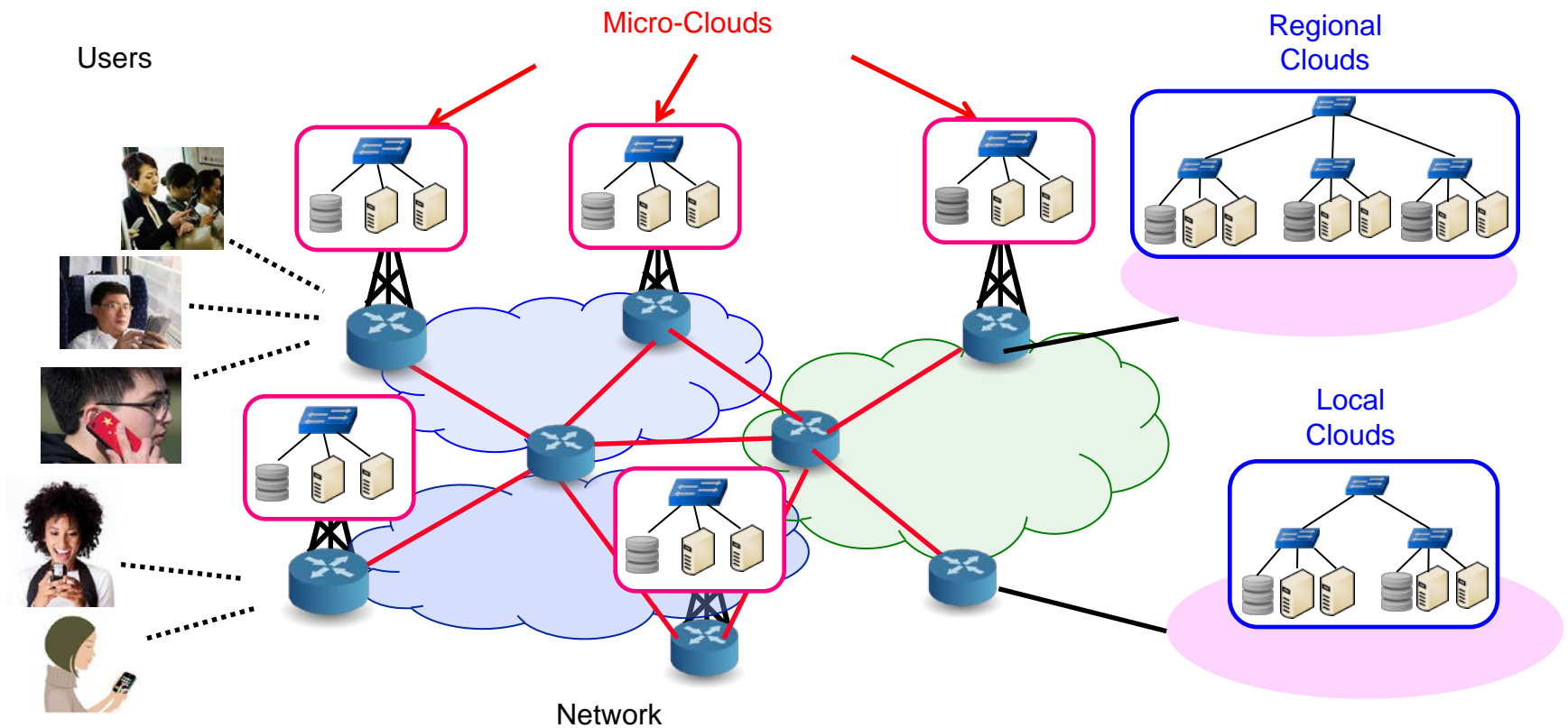
7. Micro-Services

- All major applications, such as, Facebook, Netflix, etc. consist of a number of micro-services that are instantiated on demand on virtual machines

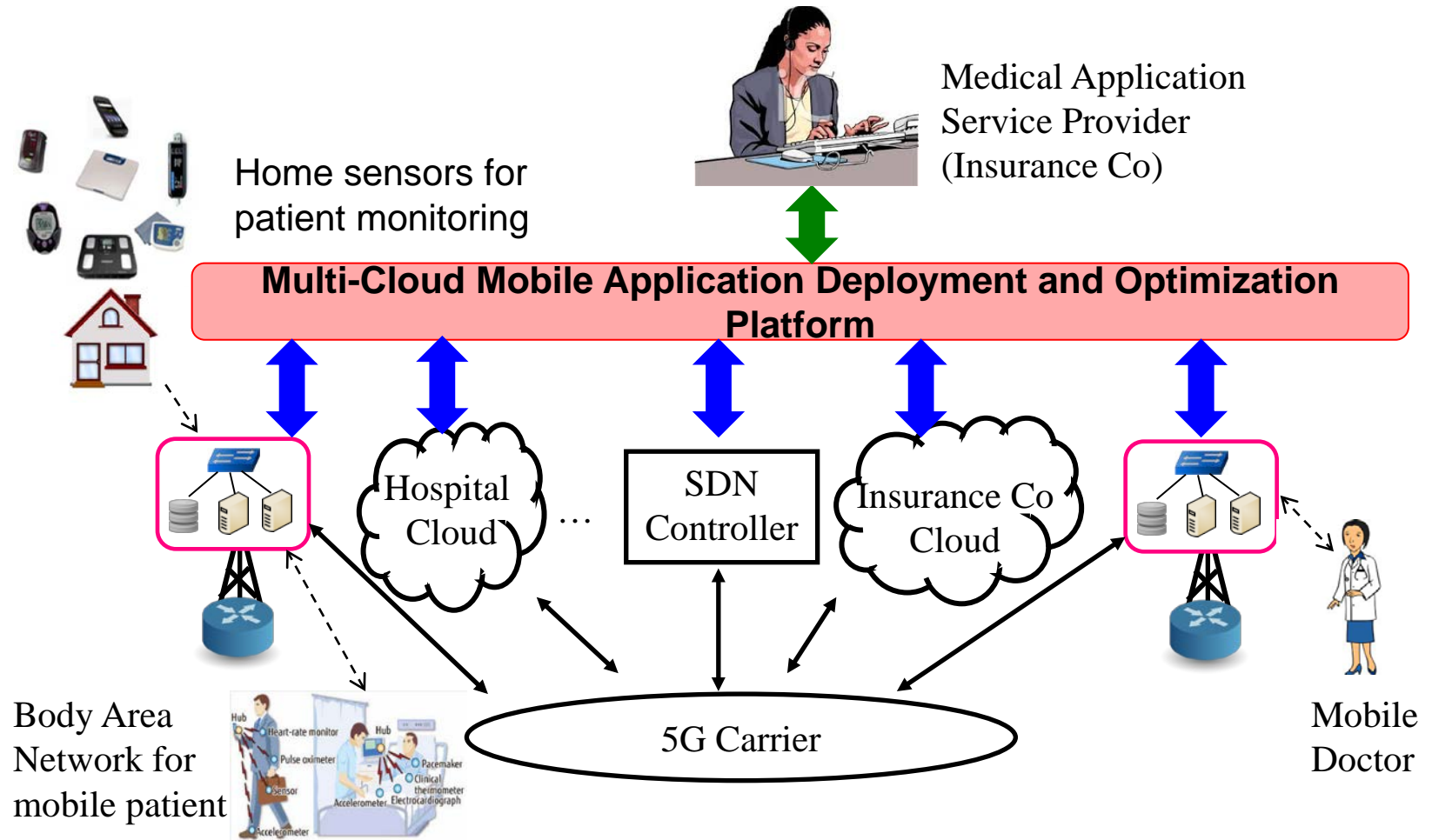


Multi-Cloud Hierarchy

- Wide area clouds, local area clouds (home routers with cloud features), Personal area clouds (cars), body area clouds (smart phone) \Rightarrow Fog Computing



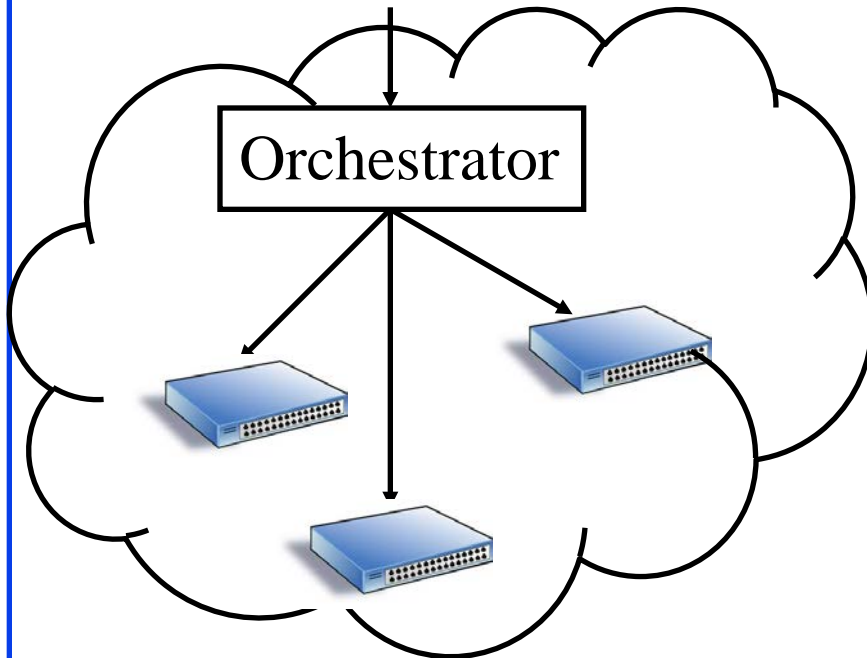
Mobile Healthcare Use Case



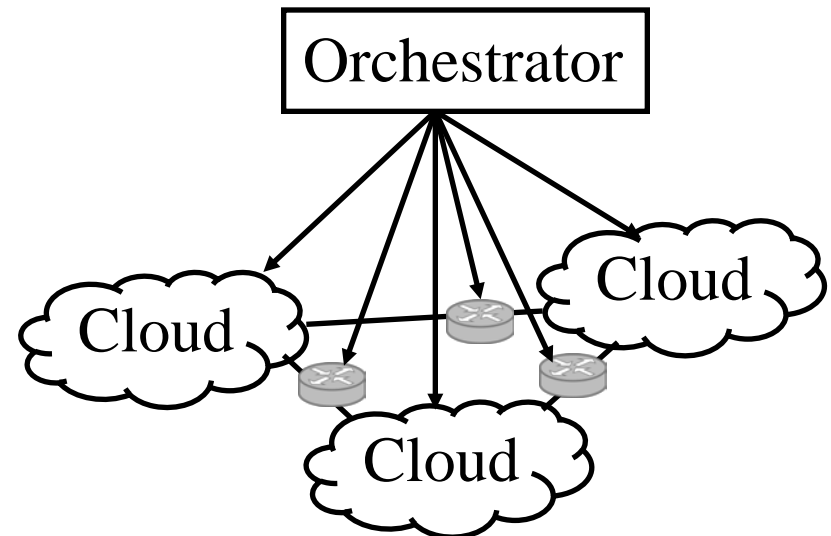
Software Defined Multi-Cloud

- ❑ Orchestrating devices to Orchestrating Clouds

Datacenter Applications



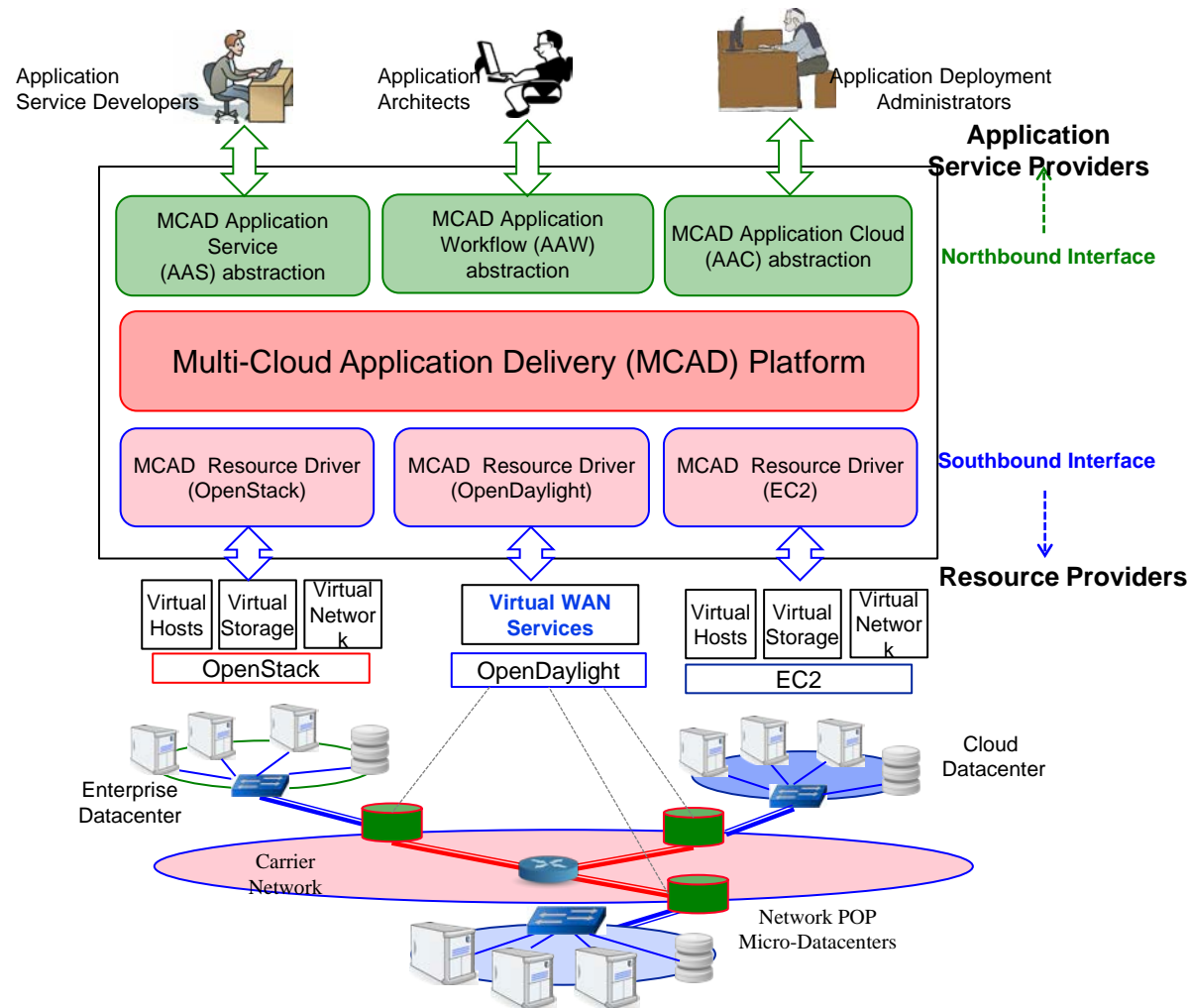
Global Applications



Ref: Subharthi Paul, Raj Jain, Mohammed Samaka, Jianli Pan, "Application Delivery in Multi-Cloud Environments using Software Defined Networking," Computer Networks Special Issue on cloud networking and communications, December 2013,

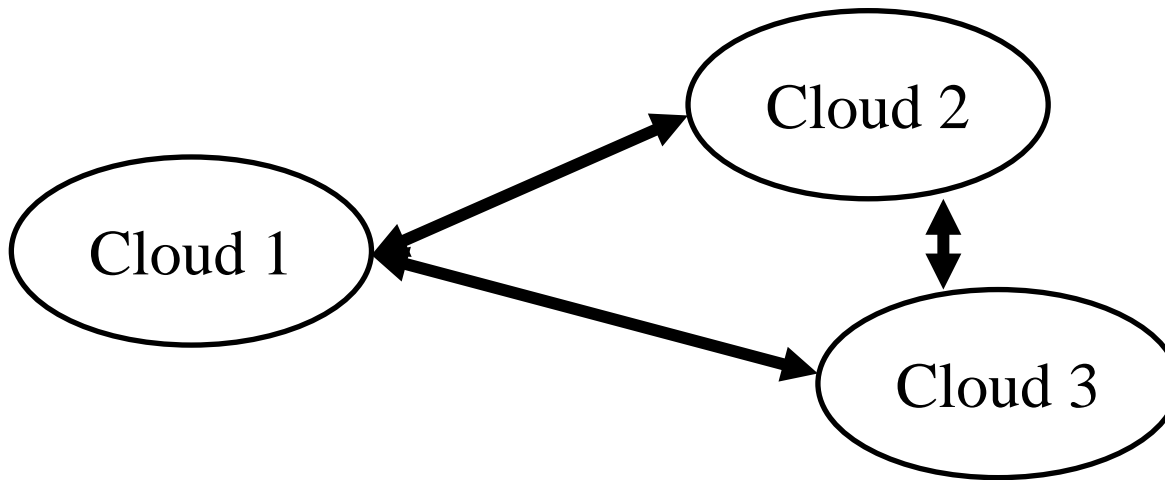
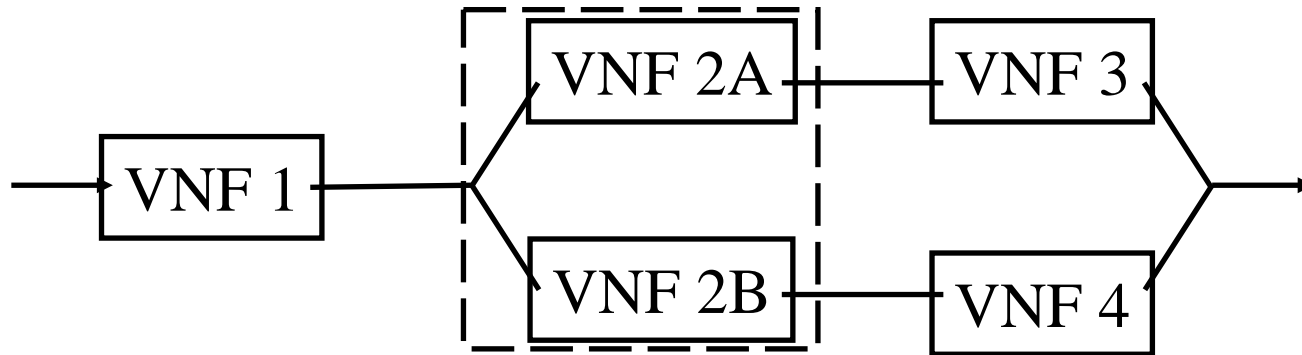
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OpenADN Multi-Cloud Management

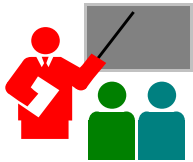


Ref: Lav Gupta, Raj Jain, Mohammed Samaka, "Analysis of Application Delivery Platform for Software Defined Infrastructures," International Journal of Communication Networks and Distributed Systems, 2016, Vol. 5, <http://www.cse.wustl.edu/~jain/papers/ijcnds16.htm>

Service Function Placement Problem



Ref: Deval Bhamare, Raj Jain, Mohammed Samaka, Aiman Erbad, "A Survey on Service Function Chaining," Journal of Network and Computer Applications, Sep 2016, 19 pp, <http://www.cse.wustl.edu/~jain/papers/jnca16.htm>



Summary

1. Clouds getting smaller.
SDN definition changing to disaggregation and orchestration
2. Carriers and enterprises moving to clouds, Internet of things are leading to clouds everywhere \Rightarrow multi-cloud applications.
 \Rightarrow Software Defined Multi-Cloud Orchestration
3. Our multi-cloud application management system (MCAD) allows policy-based deployment and management of multi-cloud application. Handles heterogeneous clouds and respects resource ownerships
4. Service function placement problem is NP complete. Challenges included delay constraints, WAN Link bottlenecks, and affinity

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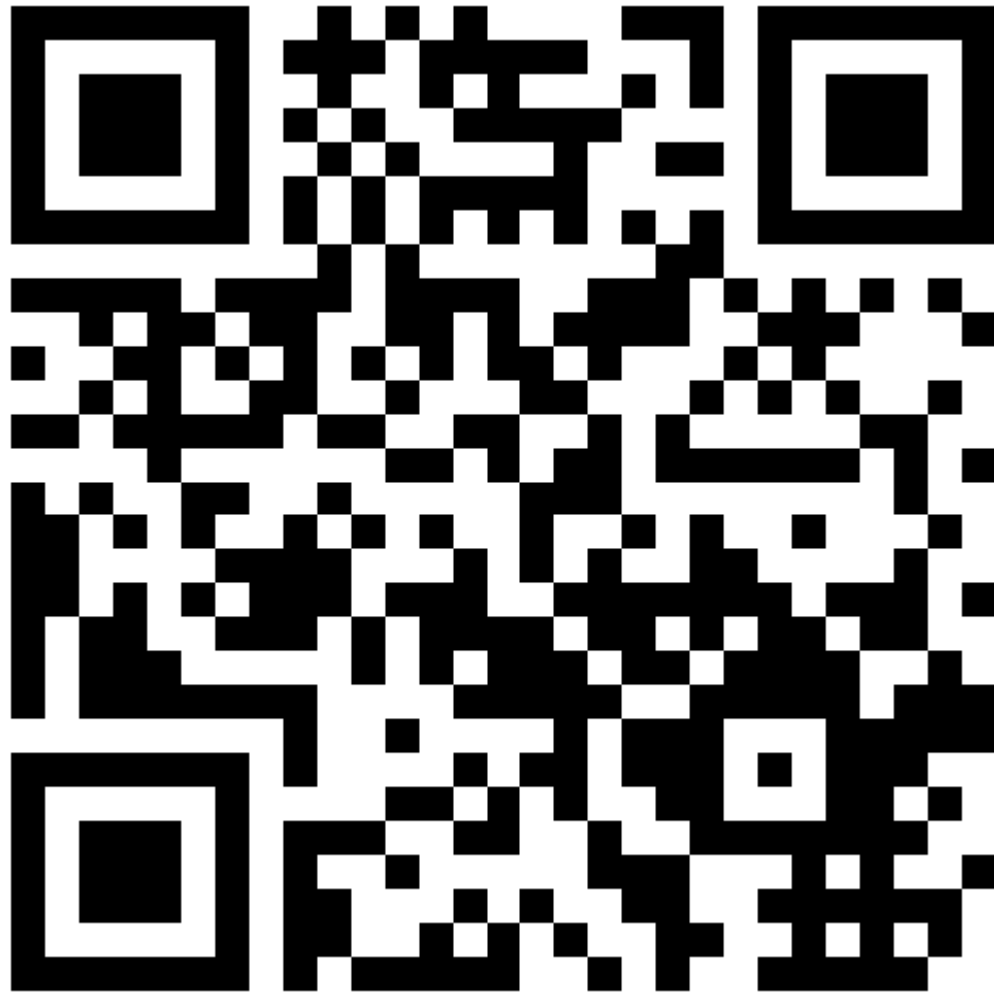
Acronyms

- ❑ ATM Asynchronous Transfer Mode
- ❑ ECN Explicit congestion notification
- ❑ EFCI Explicit Forward Congestion Indication
- ❑ FECN Forward Explicit Congestion Notification
- ❑ GB Gigabyte
- ❑ IEEE Institution of Electrical and Electronic Engineering
- ❑ IETF Internet Engineering Task Force
- ❑ IoT Internet of Things
- ❑ IP Internet Protocol
- ❑ IRTF Internet Research Task Force
- ❑ ITU International Telecommunications Union
- ❑ LAN Local Area Network
- ❑ LTE Long Term Evolution
- ❑ MHz Mega Hertz
- ❑ OpenADN Open Application Delivery Networking
- ❑ SDN Software Defined Networking

Acronyms (Cont)

- ❑ TCP Transmission Control Protocol
- ❑ TV Television
- ❑ VM Virtual Machine
- ❑ WAN Wide Area Network
- ❑ WiFi Wireless Fidelity
- ❑ WiMAX Worldwide Interoperability for Microwave Access

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