Mobile Cloud Computing over FiRST@PC

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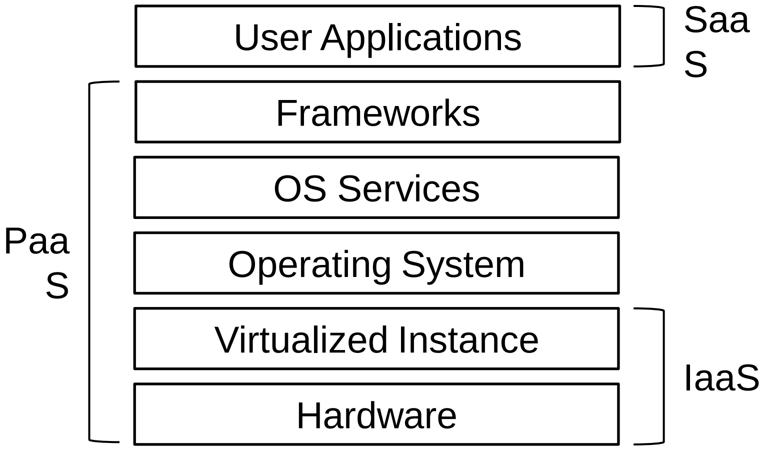
Cloud Computing Overall

- Well known cloud computing approaches
  - Infrastructure as a Service (IaaS)
    - Amazon Web Services, Eucalyptus
  - Platform as a Service (PaaS)
    - Microsoft Azure, Google App Engine
  - Software as a Service (SaaS)
    - Microsoft Office Live, Google Apps



Cloud Computing Overall

- Rising cloud computing approaches
  - Network as a Service (NaaS)
    - Network abstraction to enable network connectivity for interconnecting two VM instances, in both single/multiple virtual networks.
    - Cisco OpenStack NetworkService proposals
  - Communication as a Service (CaaS)
    - Cloud based VoIP, IM, email, video conferencing services
    - Global Crossing’s audio conference, 8x8 Inc’s video conference
  - Database as a Service (DaaS)
    - Hosts Database in the Cloud
    - Amazon Simple/Relational DB Services, Salesforce

Enabling Solutions

- Public cloud computing solutions
  - Hosted by global IT companies through huge scale CPU/Disks
  - Proprietary interfaces with own technical solutions
  - Examples
    - Amazon Web Service (IaaS)
    - MS Azure, Google App Engine (PaaS)
    - MS Office Live, Google Apps (SaaS)

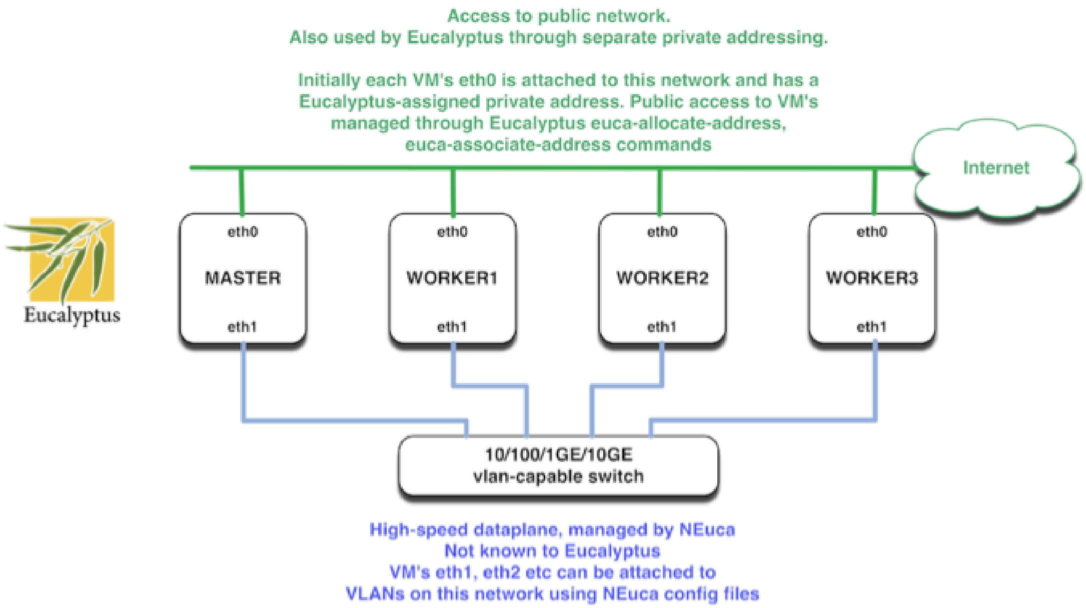
- Private cloud computing solutions
  - Hosted by private companies for own cloud construction
  - Open sources are widely used
  - Examples
    - Eucalyptus (basically open source, but license for core enhancement)

Future Internet & Cloud

- Motivation
  - Strengths of PlanetLab
    - Broad global reach
    - Large (aggregate) bandwidth and low latency to everywhere
    - Point of presence everywhere on earth
  - Weaknesses of PlanetLab
    - Not much computation available anywhere
  - Strengths of the Cloud
    - Large chunks of computation available
  - Weaknesses of the cloud
    - Bandwidth limited to a few centers
    - Latency variable

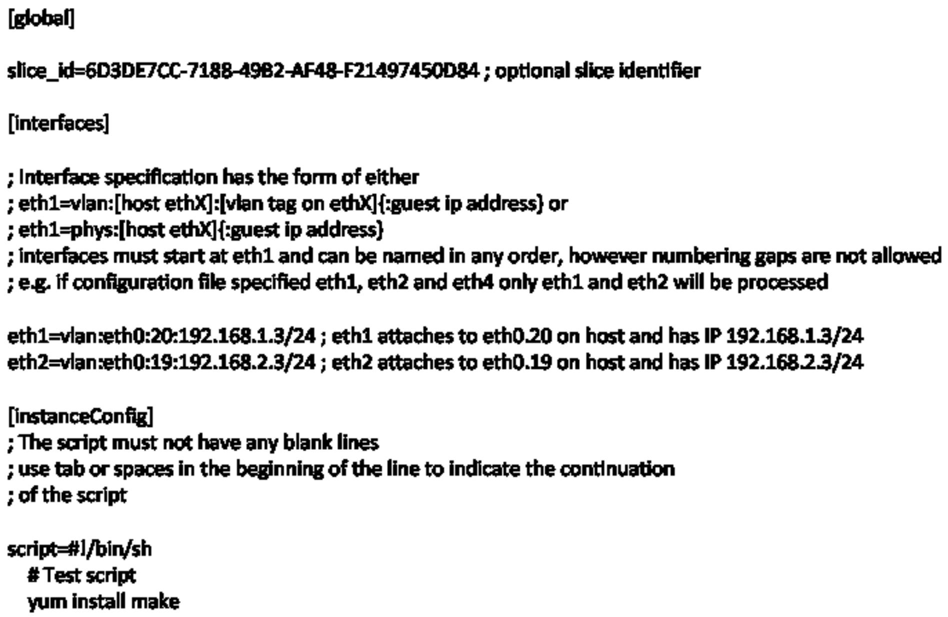
Future Internet & Cloud

- NEuca (Network Extensions to Eucalyptus)
  - Creating and configuring virtual machines with multiple network IFs attaches to VLANs or physical IFs in the host node
  - Perform arbitrary post-boot actions on guest VMs

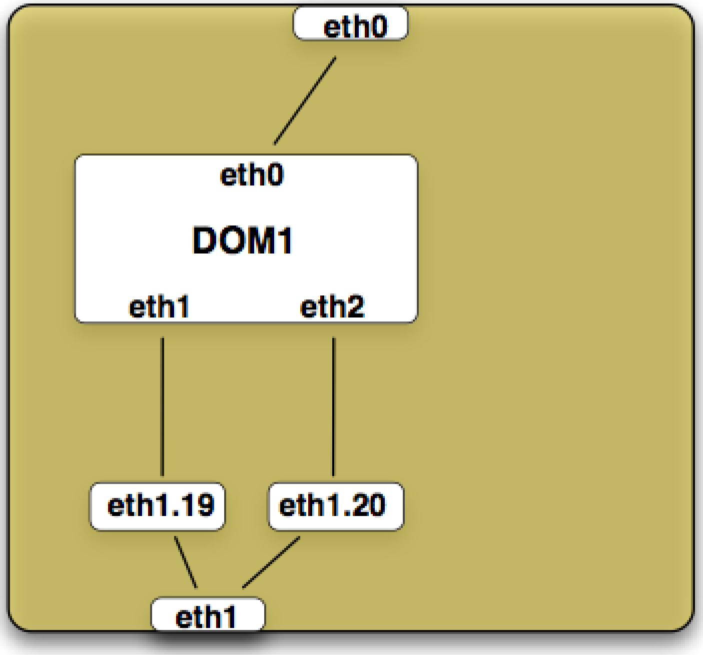

Access to public network.
Also used by Eucalyptus through separate private addressing.
Initially each VM's eth0 is attached to this network and has a Eucalyptus-assigned private address. Public access to VM's managed through Eucalyptus euca-allocate-address, euca-associate-address commands
Internet
Eucalyptus
eth0
MASTER
eth1
eth0
WORKER1
eth1
eth0
WORKER2
eth1
eth0
WORKER3
eth1
10/100/1GE/10GE
vlan-capable switch
High-speed dataplane, managed by NEuca
Not known to Eucalyptus
VM's eth1, eth2 etc can be attached to
VLANs on this network using NEuca config files

Future Internet & Cloud

- NEuca
  - Example cases



```
[global]

slice_id=6D3DE7CC-7188-4982-AF48-F21497450D84 ; optional slice identifier

[interfaces]

; Interface specification has the form of either
; eth1=vlan:[host ethX]:[vlan tag on ethX]{:guest ip address} or
; eth1=phys:[host ethX]{:guest ip address}
; interfaces must start at eth1 and can be named in any order, however numbering gaps are not allowed
; e.g. if configuration file specified eth1, eth2 and eth4 only eth1 and eth2 will be processed

eth1=vlan:eth0:20:192.168.1.3/24 ; eth1 attaches to eth0.20 on host and has IP 192.168.1.3/24
eth2=vlan:eth0:19:192.168.2.3/24 ; eth2 attaches to eth0.19 on host and has IP 192.168.2.3/24

[instanceConfig]
; The script must not have any blank lines
; use tab or spaces in the beginning of the line to indicate the continuation
; of the script

script=#!/bin/sh
   # Test script
   yum install make
```



Future Internet & Cloud

- GENIcloud
  - Eucalyptus cloud computing under PlanetLab’s Slice-based Facility Architecture (SFA)
  - Experimenter can use cloud resource through SFA

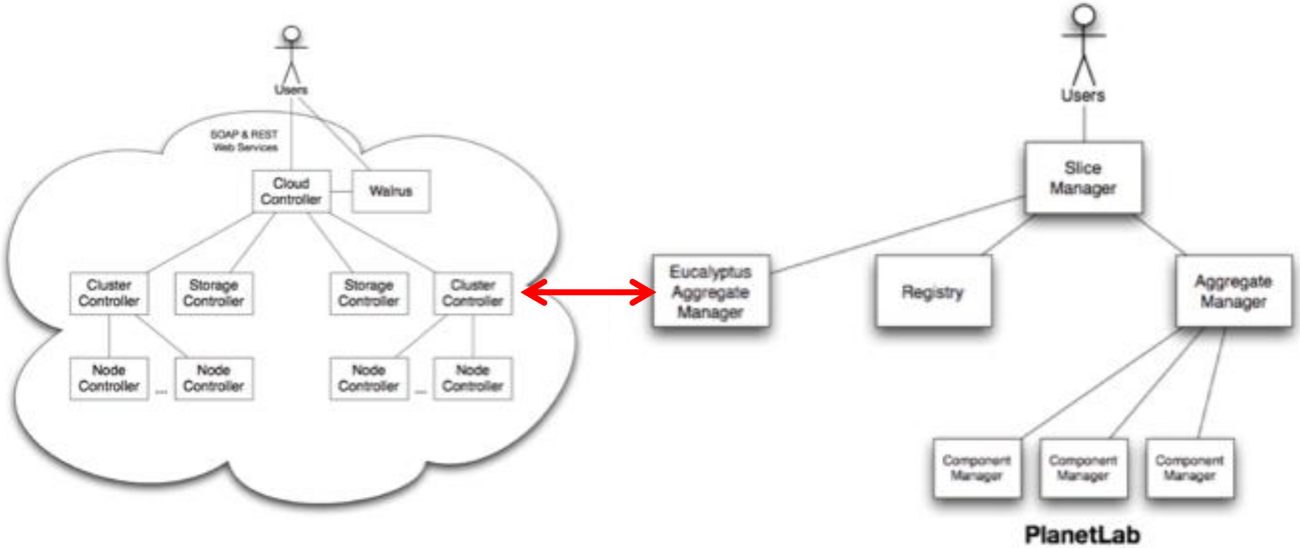
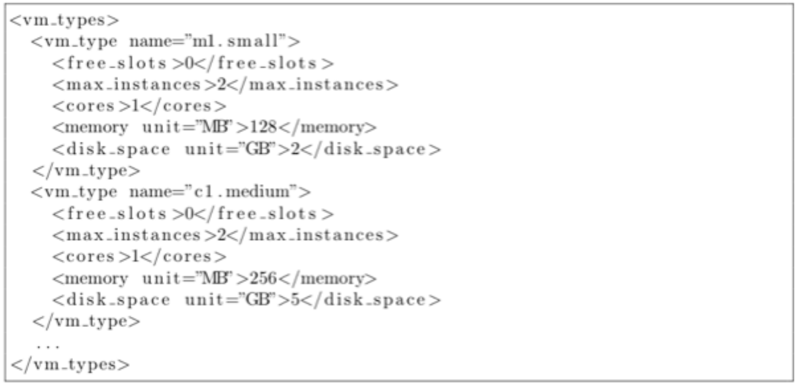


Figure 1.2: Components in Eucalyptus

Figure 3.5: GENICloud Architecture

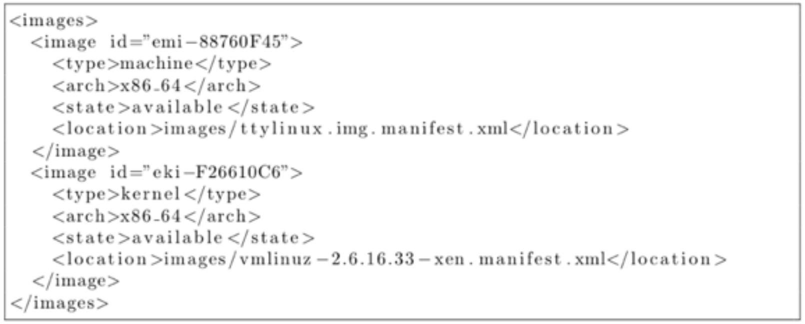
Future Internet & Cloud

- GENIcloud
  - Implementation focus on Eucalyptus Aggregate Manager
  - Mapping between slice and instance is implemented via DB
  - RSpec is extended for Cloud Resource management



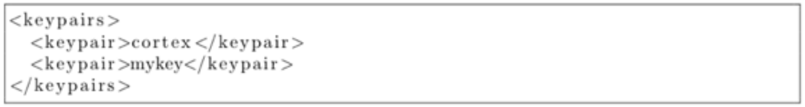
```
<vm_types>
  <vm_type name=”m1.small”>
    <free_slots>0</free_slots>
    <max_instances>2</max_instances>
    <cores>1</cores>
    <memory unit=”MB”>128</memory>
    <disk_space unit=”GB”>2</disk_space>
  </vm_type>
  <vm_type name=”c1.medium”>
    <free_slots>0</free_slots>
    <max_instances>2</max_instances>
    <cores>1</cores>
    <memory unit=”MB”>256</memory>
    <disk_space unit=”GB”>5</disk_space>
  </vm_type>
  ...
</vm_types>
```

Listing 4.1: An excerpt from the RSpec showing the different types of instances in the cloud



```
<images>
  <image id=”emi−88760F45”>
    <type>machine</type>
    <arch>x86_64</arch>
    <state>available</state>
    <location>images/ttylinux.img.manifest.xml</location>
  </image>
  <image id=”eki−F26610C6”>
    <type>kernel</type>
    <arch>x86_64</arch>
    <state>available</state>
    <location>images/vmlinuz−2.6.16.33−xen.manifest.xml</location>
  </image>
</images>
```

Listing 4.2: The different images (e.g., disk images, kernel images) for instances

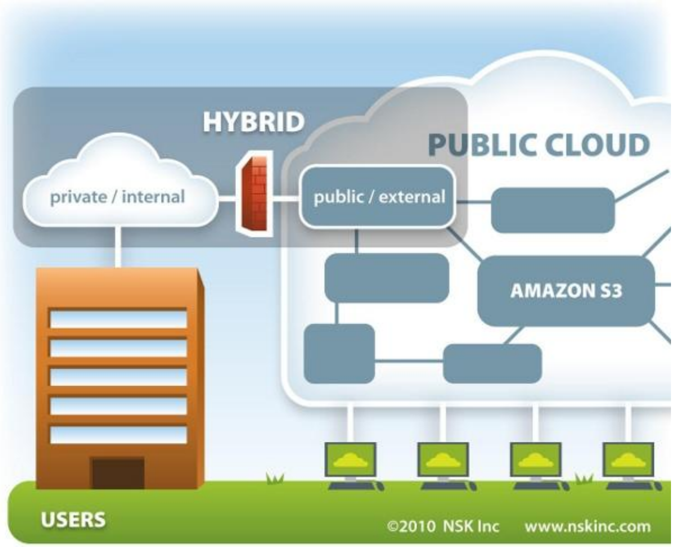


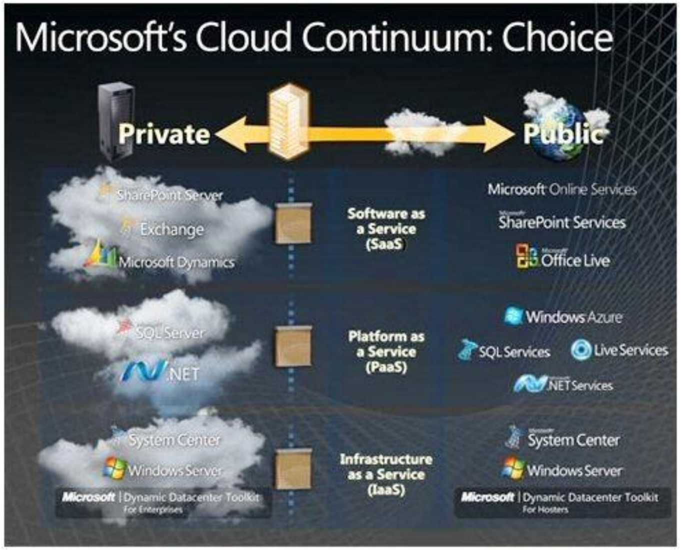
```
<keypairs>
  <keypair>cortex</keypair>
  <keypair>mykey</keypair>
</keypairs>
```

Listing 4.3: The keypairs in the cloud

Paradigm Change

- **Public** cloud to **Hybrid** cloud
  - Organization wants to have control over their data storage, but needs additional space for archiving data
  - They have the security and supervision of the Private Cloud in their network, but can store excess data in a scalable on-demand Public Cloud




Microsoft's Cloud Continuum: Choice
Private
Public
SharePoint Server
Exchange
Microsoft Dynamics
Software as a Service (SaaS)
Microsoft Online Services
SharePoint Services
Office Live
SQL Server
.NET
Platform as a Service (PaaS)
Windows Azure
SQL Services
Live Services
.NET Services
System Center
Windows Server
Infrastructure as a Service (IaaS)
System Center
Windows Server
Microsoft | Dynamic Datacenter Toolkit For Enterprises
Microsoft | Dynamic Datacenter Toolkit For Hosters

Challenging Problems

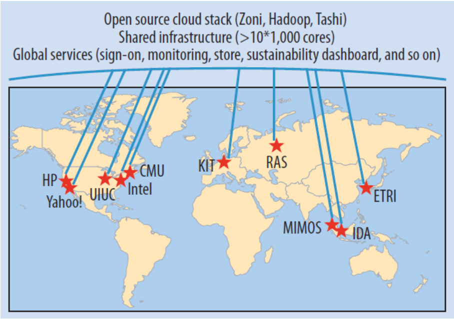
- Interoperability
  - Between Public clouds
  - Between Public and Private clouds
- Open Source Cloud Computing Solutions
  - Fully open source Compute/Storage service solutions
  - Can be applied for both private and public clouds
- Network Virtualization
  - Isolated virtualized networks in the cloud
  - Secure and QoS guaranteed networks between clouds
- Mobile (Cloud) Network
  - Seamless connectivity
  - Optimized performance over dynamic wireless links

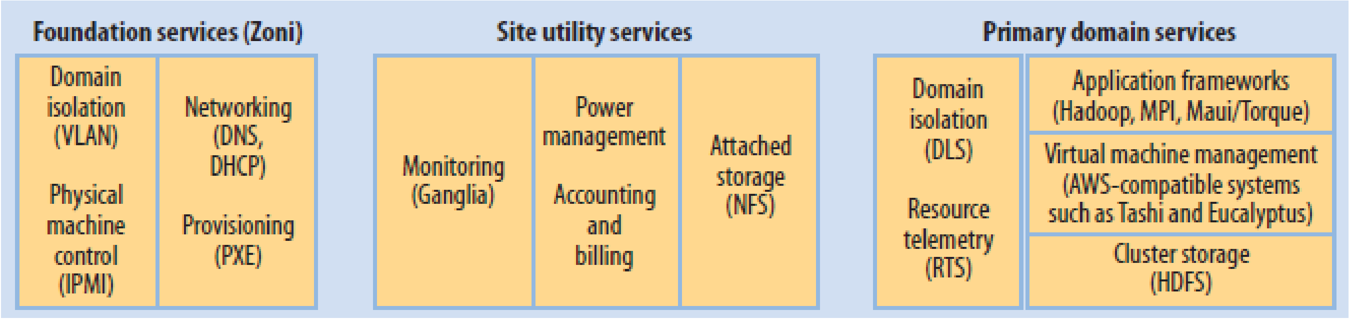
Interoperability

- OpenCirrus
  - Open cloud-computing **research testbed**
  - Designed to support research into the design, provisioning, and management of services at a global, multi-datacenter scale
- KOALA
  - Karlsruhe Open Application for cLoud Administration
  - **Open Source Software service** to help working with Amazon Web Services compatible cloud services and infrastructures (IaaS)
  - Amazon, Eucalyptus, Nimbus or OpenNebula are supported
- IEEE P2301/P2302
  - P2301: **Guide** for Cloud Portability and Interoperability Profiles (CPIP)
  - P2302: **Standard** for Intercloud Interoperability and Federation (SIIF)

Interoperability

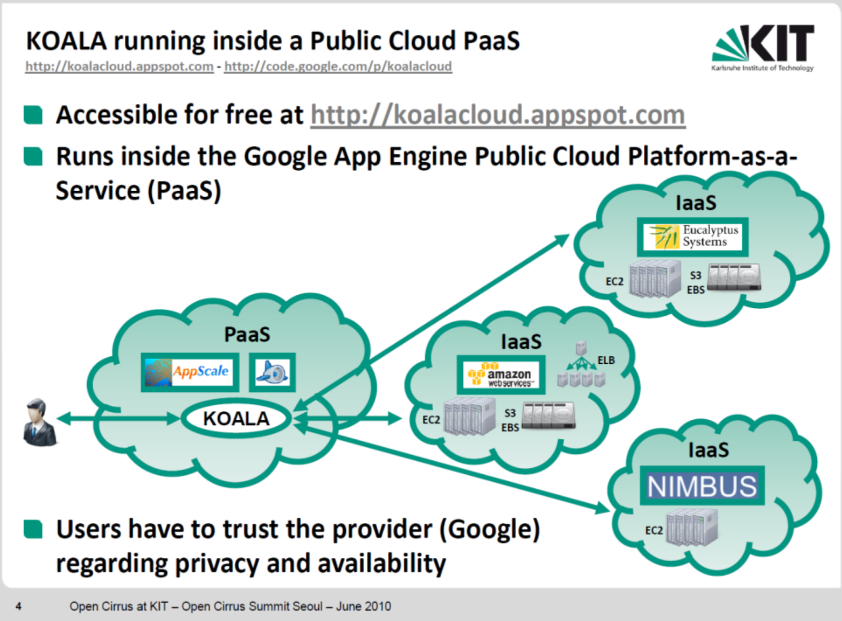
- OpenCirrus
  - **Federation** between distributed data centers
  - Goals
    - aims to foster systems-level research in cloud computing
    - encourage new cloud computing applications and applications research
    - offers a collection of experimental data
    - aims to develop open source stacks and APIs for the cloud


Open source cloud stack (Zoni, Hadoop, Tashi)
Shared infrastructure (>10*1,000 cores)
Global services (sign-on, monitoring, store, sustainability dashboard, and so on)
HP
Yahoo!
UIUC
CMU
Intel
KIT
RAS
ETRI
MIMOS
IDA



Interoperability

- KOALA
  - **Open Source** : Apache License 2.0
  - Implemented in Python and HTML
  - Project Site: http://code.google.com/p/koalacloud/



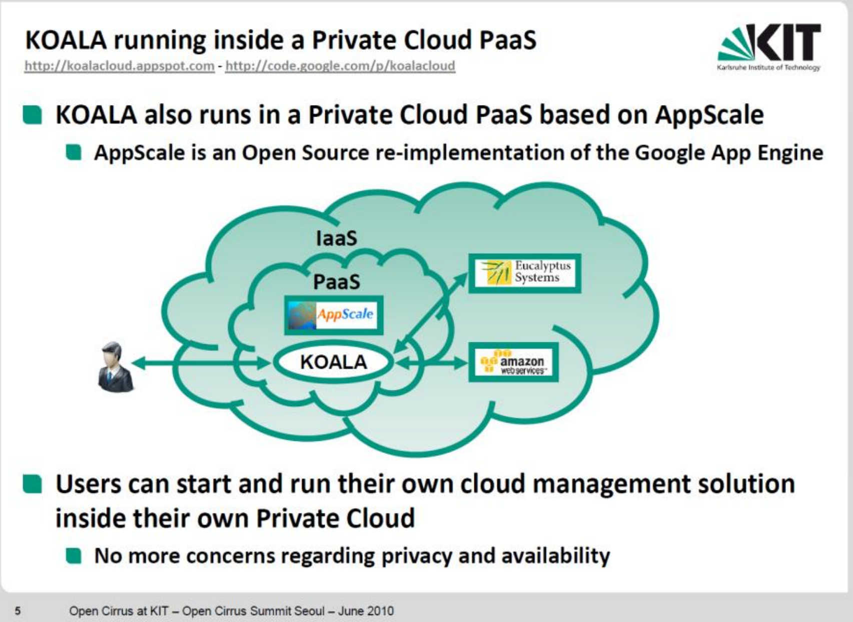
KOALA running inside a Public Cloud PaaS

http://koalacloud.appspot.com - http://code.google.com/p/koalacloud

KIT Karlsruhe Institute of Technology

- Accessible for free at http://koalacloud.appspot.com
- Runs inside the Google App Engine Public Cloud Platform-as-a-Service (PaaS)
- Users have to trust the provider (Google) regarding privacy and availability

4 Open Cirrus at KIT – Open Cirrus Summit Seoul – June 2010



KOALA running inside a Private Cloud PaaS

http://koalacloud.appspot.com - http://code.google.com/p/koalacloud

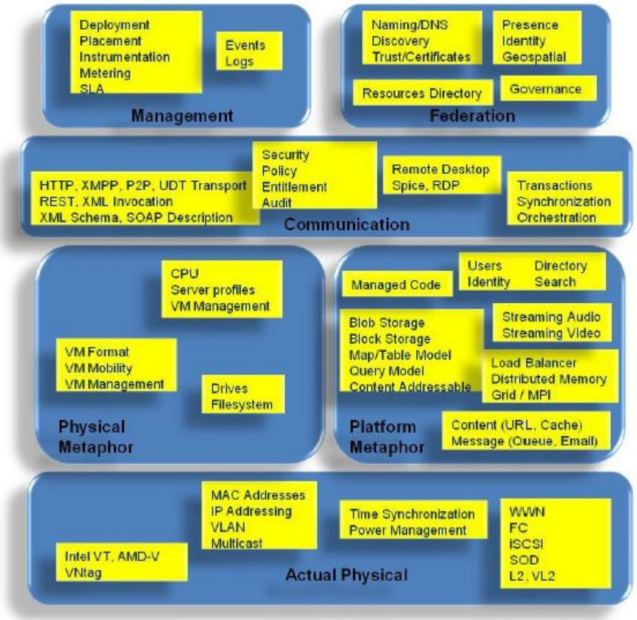
KIT Karlsruhe Institute of Technology

- KOALA also runs in a Private Cloud PaaS based on AppScale
  - AppScale is an Open Source re-implementation of the Google App Engine
- Users can start and run their own cloud management solution inside their own Private Cloud
  - No more concerns regarding privacy and availability

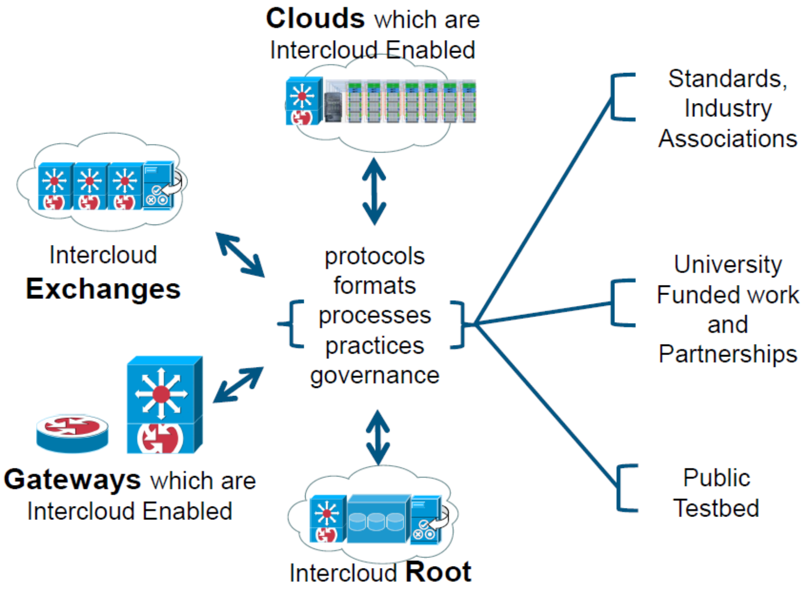
5 Open Cirrus at KIT – Open Cirrus Summit Seoul – June 2010

Interoperability

- IEEE P2301/P2302
  - IEEE **standards** for intercloud federation



P2301 Profile Examples



P2302 Federation Standard Examples

Open Source

Eucalyptus Systems openstack CLOUD SOFTWARE

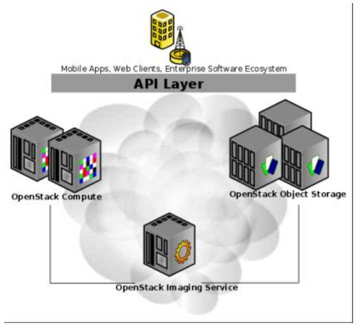
- Eucalyptus vs. OpenStack
  - Industrial deployment
    - Ubuntu will supports OpenStack as default cloud fabric (instead of EUCA)
    - Ubuntu 11.10 (at this December) will be the 1st release with OpenStack
  - Openness
    - Eucalyptus request license for Core feature modification
    - OpenStack is fully open source
  - Ownership
    - Eucalyptus Systems, Inc. manages Eucalyptus
    - NASA & Rackspace made OpenStack and fully opened
  - Customer deployment
    - 25,000 IaaS clouds are based on Eucalyptus & 56 partners
    - 20,000 downloads are marked for OpenStack & 72 partners
      - Including NTT, KT, Intel, AMD, Citrix, Cisco, Extreme Networks, etc.

Open Source

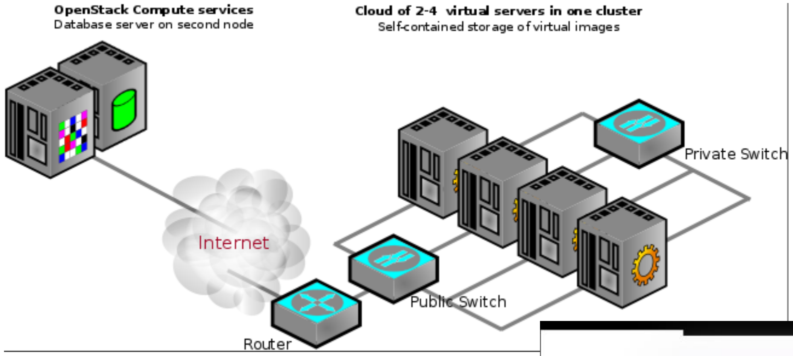
- OpenStack Components
  - Compute
    - Cloud fabric controller to start up virtual instances for either a user or a group
    - Configure networking for each instance or project that contains multiple instances for a particular project
  - Object Storage
    - Store objects in a massively scalable large capacity system with built-in redundancy and failover
    - Provides variety of applications: 1) backing up or archiving data, 2) serving graphics or videos (streaming data to a user’s browser), 3) serving content with a Content Delivery Network (CDN), 4) storing secondary or tertiary static data, developing new applications with data storage integration, 5) storing data when predicting storage capacity is difficult, and 6) creating the elasticity and flexibility of cloud-based storage for your web applications.
  - Image Service
    - Retrieval system for virtual machine images
    - configured in three ways: 1) using OpenStack Object Store to store images; 2)using Amazon's Simple Storage Solution (S3) storage directly; or 3) using S3 storage with Object Store as the intermediate for S3 access

Open Source

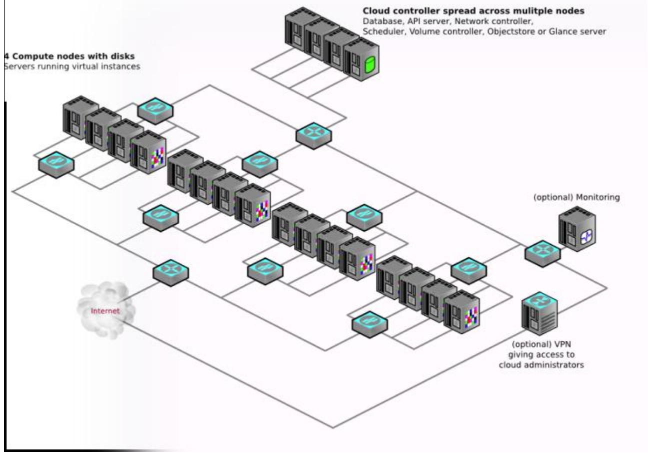
- OpenStack Installations


Mobile Apps, Web Clients, Enterprise Software Ecosystem
API Layer
OpenStack Compute
OpenStack Object Storage
OpenStack Imaging Service

Single Node


OpenStack Compute services
Database server on second node
Cloud of 2-4 virtual servers in one cluster
Self-contained storage of virtual images
Private Switch
Internet
Public Switch
Router

Two Nodes


Cloud controller spread across mulitple nodes
Database, API server, Network controller,
Scheduler, Volume controller, Objectstore or Glance server
4 Compute nodes with disks
Servers running virtual instances
(optional) Monitoring
Internet
(optional) VPN
giving access to
cloud administrators

Multi Nodes

❖ Networking Modes

- VLAN supports (default)

- Supports both Floating/Fixed IP

Networking

- Initial Phase for Cloud networking
  - How will cloud services and applications utilize network capabilities such as routing, bandwidth management, VPN creation and configuration, network segmentation and isolation, and so on?
  - How do you present network concepts in a form that is meaningful for application development and operations?
  - How will OpenStack support that from a global networking perspective, such as VPNs, VRFs, VLANs, MPLS connections, and so on be provisioned and operated in a highly distributed, dynamic environments?

Networking

- Cisco’s OpenStack:NaaS Proposal (2011-04-06)
  - Provides a network abstraction layer and set of APIs to enable Requesting and acquiring network connectivity by *Compute* for interconnecting two VM instances , both single virtual network (single vnic) or multi vnics to different virtual networks.

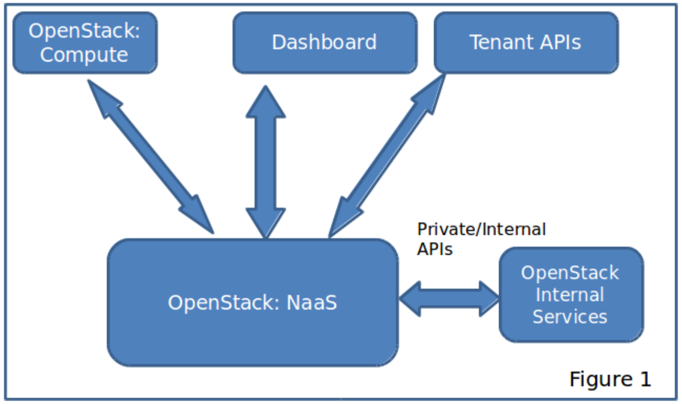
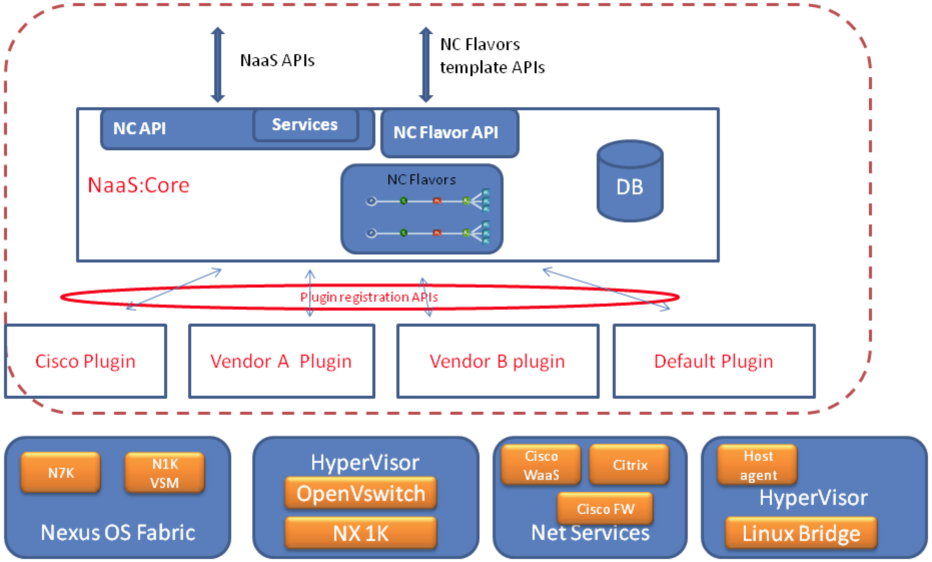


Figure 1



Mobile Cloud Computing

- Background
  - Conventional cloud targets to IT infrastructure efficiency
    - Especially for intranet infrastructure efficiency
  - How mobile/telco operators make money via cloud computing?
    - Cloud based Telco. operator’s service and business model

- Goals
  - Win-Win business model between ISP and NSP
  - Also, benefits for mobile users (in performance, cost, etc)

Mobile Cloud Computing

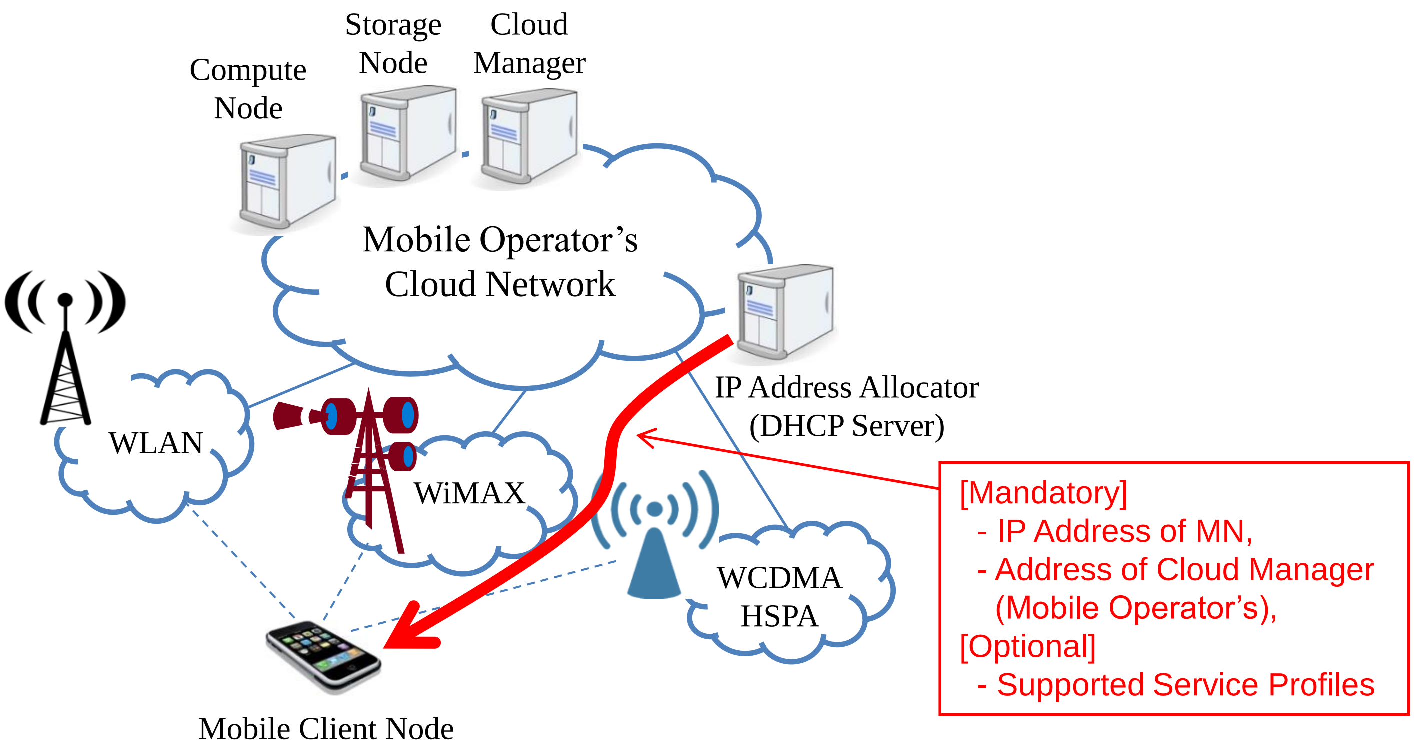
- Design Principles
  - NSP (Telco/Mobile operator) as a local cloud provider
  - Isolated secure & virtual network in NSP's cloud
  - Fast response between client and server (without WAN effect)
  - Rich-full mobile feature (location, MPTCP, compression, etc.)
  - Biz chance for small innovative companies
  - CDN feature supports

Mobile Cloud Computing

- Characteristics
  - Cloud aware mobile node
  - Cloud mobility
  - Cloud service for mobile node
    - Scenario.1: Mobile thin client
    - Scenario.2: Mobile zero client
    - Scenario.3: Mobile proactive client
  - Mobile network as a Service (M.NaaS) *[Actually not limited for mobile network]*
    - Accelerated transport layer protocol
    - Network address independent transport layer protocol
    - High speed data synchronization between Local & Remote cloud
    - Mobile aware & optimized remote desktop protocol
    - Mobile network aware intelligent cloud

Cloud aware Mobile Node

- Mobile Node identifies Mobile Cloud
  - Mobile operator constructs own cloud network
  - Address of cloud manager is transferred to Mobile Node

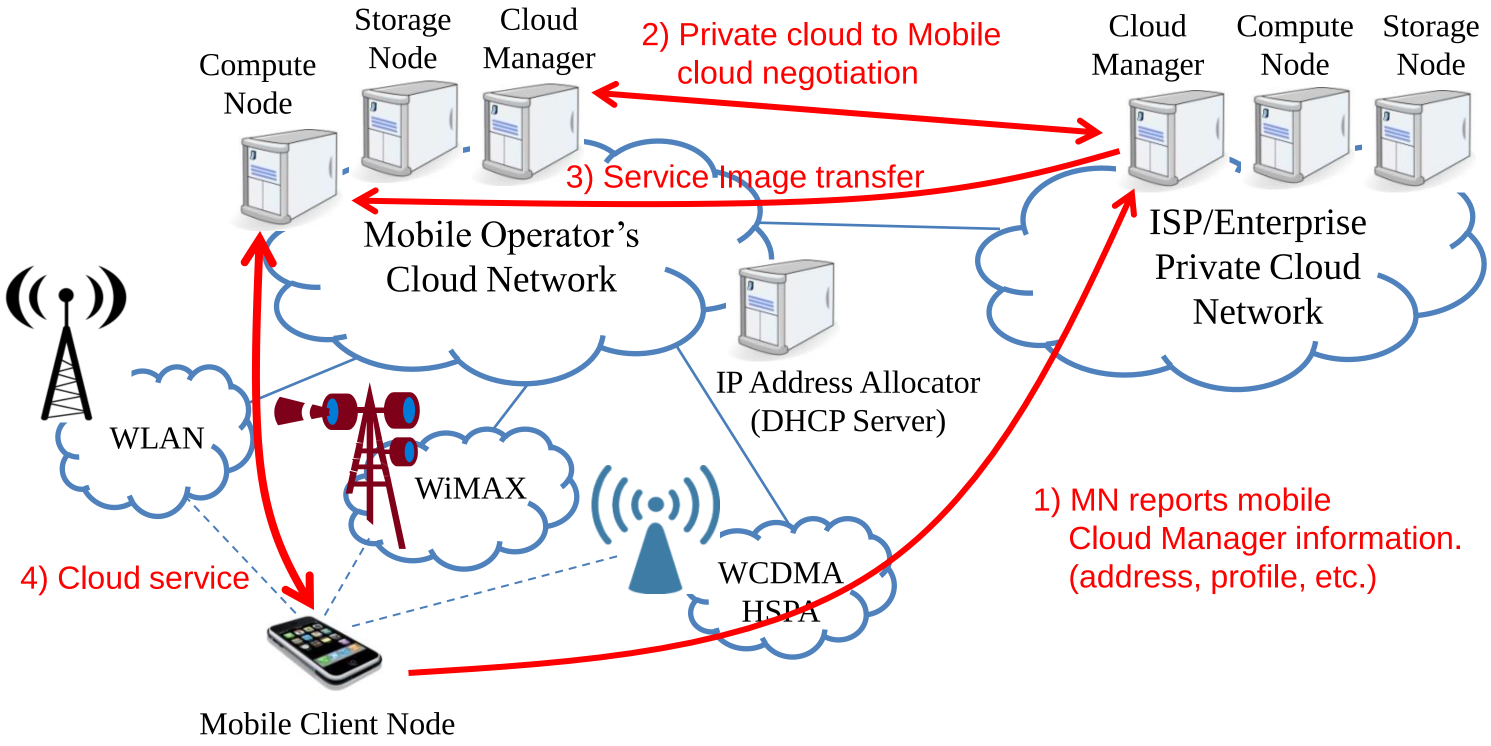


[Mandatory]
- IP Address of MN,
- Address of Cloud Manager (Mobile Operator’s),

[Optional]
- Supported Service Profiles

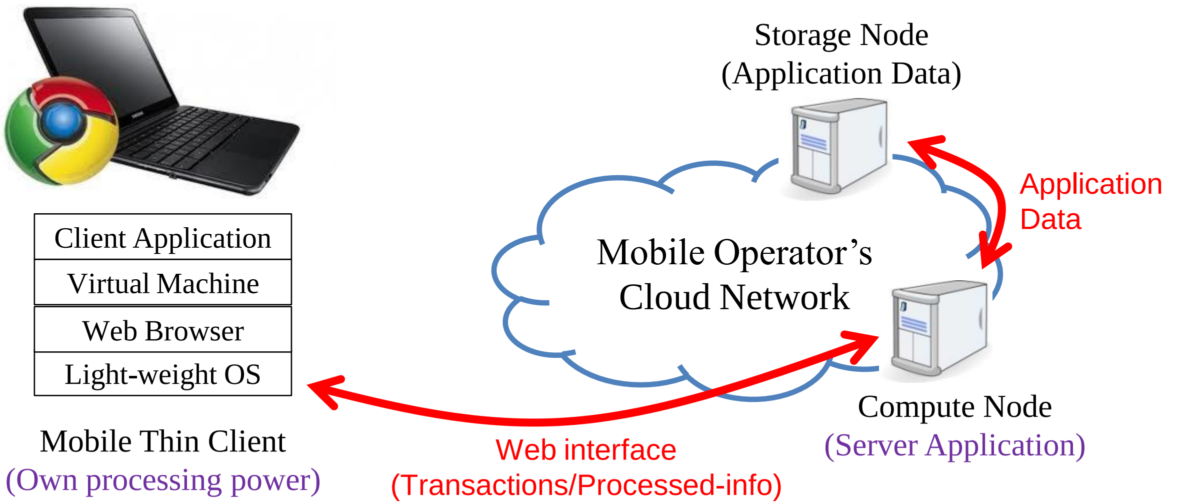
Cloud Mobility

- Cloud service transferred into Mobile Cloud
  - Inter-cloud service transfer between ISP/Enterprise private cloud and mobile operator’s mobile cloud


Compute Node
Storage Node
Cloud Manager
2) Private cloud to Mobile cloud negotiation
Cloud Manager
Compute Node
Storage Node
3) Service Image transfer
Mobile Operator’s Cloud Network
ISP/Enterprise Private Cloud Network
IP Address Allocator (DHCP Server)
WLAN
WiMAX
WCDMA HSPA
4) Cloud service
1) MN reports mobile Cloud Manager information. (address, profile, etc.)
Mobile Client Node

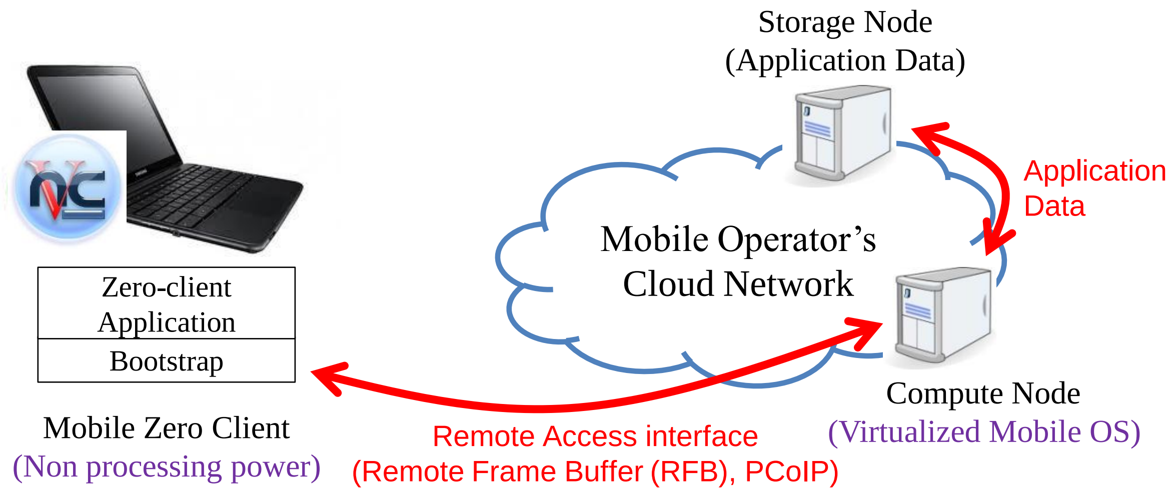
Mobile Thin-client Service Scenario

- Client-Server architecture over Mobile Cloud
  - Mobile node has processing power, and execute client application
  - Server application executed on Mobile Cloud
  - Conventional web based client/server interface used
  - Example: Google Chromium OS, Conventional Smart-Pad/Phone



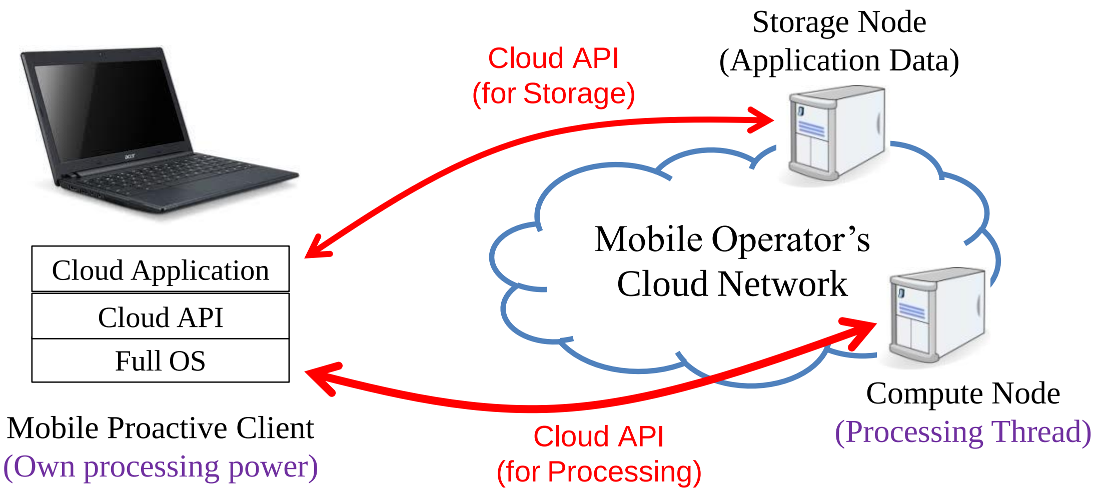
Mobile Zero-client Service Scenario

- VNC-terminal like service over Mobile Cloud
  - Mobile node has non processing power, and execute remote viewer
  - Cloud supports mobile OS (Android, iOS) virtualization
  - Remote Frame Buffer like interface between client and cloud
  - Example: http://www.android-x86.org/



Mobile Proactive-client Service Scenario

- Proactive Cloud application over Mobile Cloud
  - Mobile node execute own Cloud service (directly use cloud API)
  - Cloud node used as extended CPU or Storage
  - Cloud API is used between client and cloud
  - Example: None

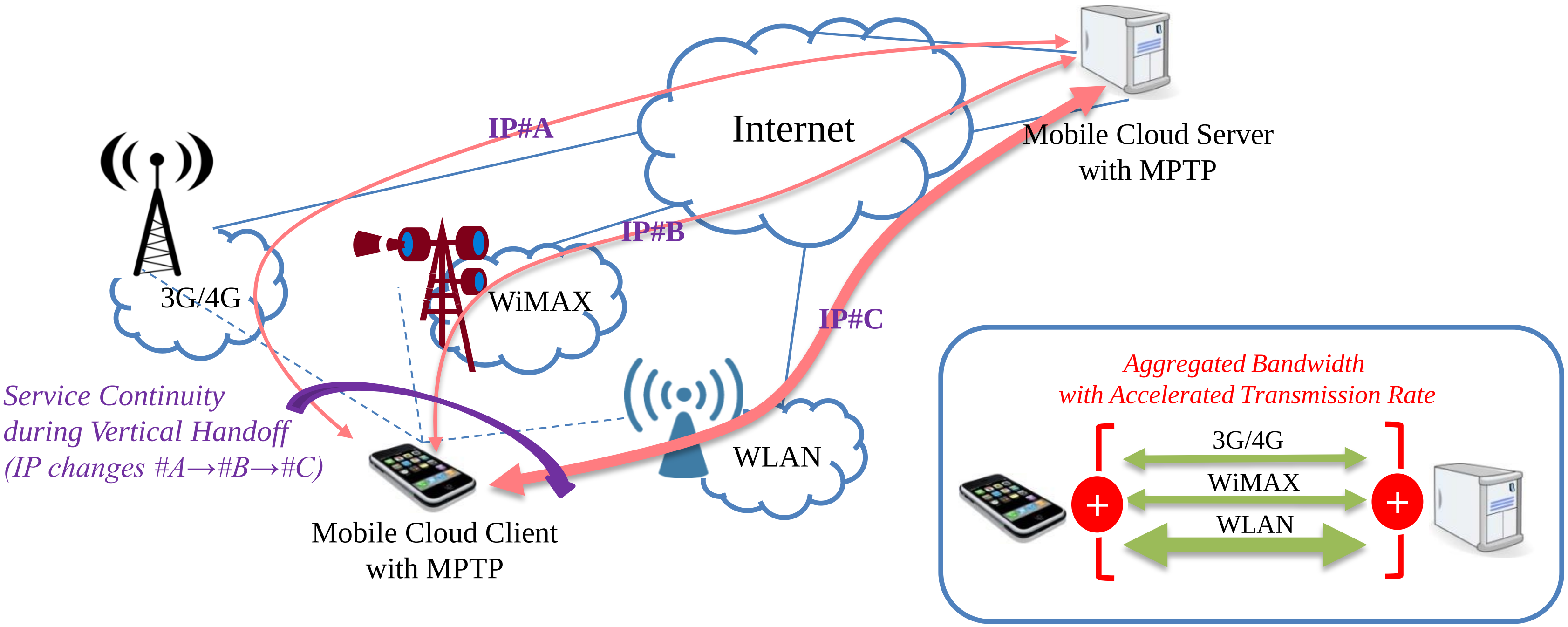


Mobile Network as a Service

- Accelerated transport layer protocol
  - Easy to deploy
    - Software issue for client and cloud server (between specific peers)
  - Example cases
    - MS Cloud Faster (MS Research)
      - DCTCP (Data Center TCP), WideArea TCP
      - Increase initial CWND
      - Intelligent multi-bit ECN for congestion control and fast adaptation
    - Google SPDY (Chromium project)
      - Experimental protocols to reduce the latency of web pages
      - Enhancement for TCP slow start
      - Binary compression for human readable coded contents
      - Multi path transmission for single TCP connection

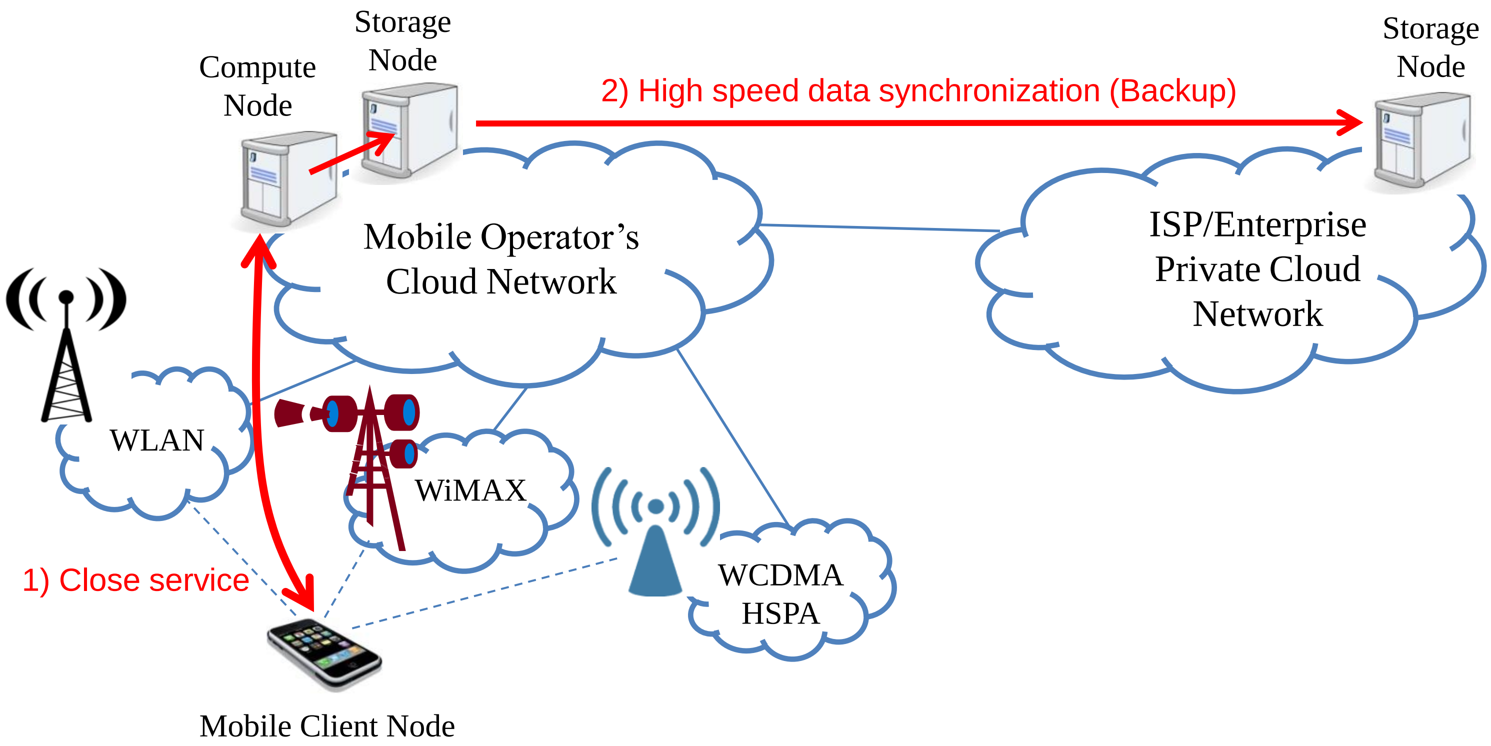
Mobile Network as a Service

- Network address independent transport layer protocol
  - IETF Standards
    - TCP Extensions for Multipath Operation with Multiple Addresses
    - Coupled Congestion Control for Multipath Transport Protocols
    - Architectural Guidelines for Multipath TCP Development
    - MultiPath TCP: Guidelines for implementers


Internet
Mobile Cloud Server with MPTP
IP#A
IP#B
IP#C
3G/4G
WiMAX
WLAN
Service Continuity during Vertical Handoff (IP changes #A→#B→#C)
Mobile Cloud Client with MPTP
Aggregated Bandwidth with Accelerated Transmission Rate
3G/4G
WiMAX
WLAN
+
+

Mobile Network as a Service

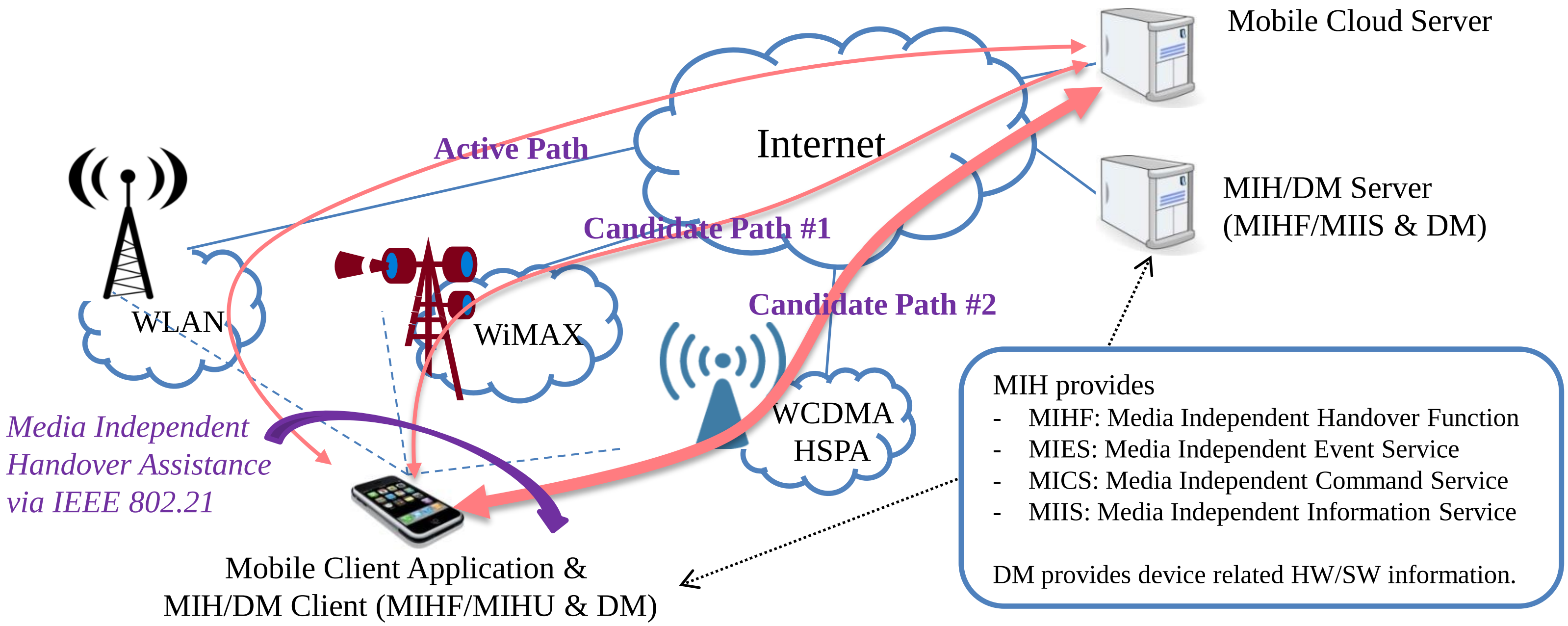
- High speed data synchronization
  - Data synchronization required between clouds
    - Uni-directional backup for released service
    - Bi-directional real-time synchronization for interactive services



Storage Node
Compute Node
2) High speed data synchronization (Backup)
Storage Node
Mobile Operator’s Cloud Network
ISP/Enterprise Private Cloud Network
WLAN
WiMAX
WCDMA HSPA
1) Close service
Mobile Client Node

Mobile Network as a Service

- Mobile network aware intelligent cloud
  - Mobile cloud server aware heterogeneous networks and device info.
  - Mobile cloud server initiates the handover for best wireless links
  - Mobile cloud server optimizes the contents for device characteristics

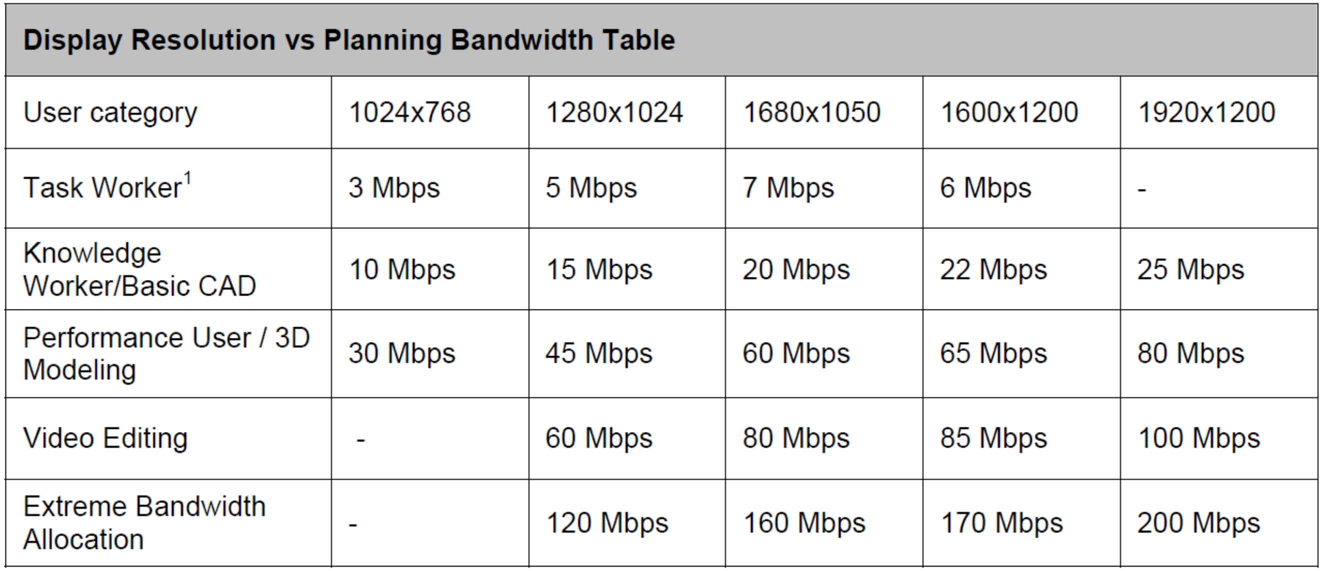


MIH provides
- MIHF: Media Independent Handover Function
- MIES: Media Independent Event Service
- MICS: Media Independent Command Service
- MIIS: Media Independent Information Service

DM provides device related HW/SW information.

Mobile Network as a Service

- Mobile aware & optimized remote desktop protocol
  - Enhancement of RFB/PCoIP for wireless links



Display Resolution vs Planning Bandwidth Table

User category	1024x768	1280x1024	1680x1050	1600x1200	1920x1200
Task Worker[1]	3 Mbps	5 Mbps	7 Mbps	6 Mbps	-
Knowledge Worker/Basic CAD	10 Mbps	15 Mbps	20 Mbps	22 Mbps	25 Mbps
Performance User / 3D Modeling	30 Mbps	45 Mbps	60 Mbps	65 Mbps	80 Mbps
Video Editing	-	60 Mbps	80 Mbps	85 Mbps	100 Mbps
Extreme Bandwidth Allocation	-	120 Mbps	160 Mbps	170 Mbps	200 Mbps

KHU Mobile Cloud Evolution

- Today
  - Eucalyptus cloud deployed
  - “Cloud mobility” designed and developed over Eucalyptus [key contribution]
  - NEuca deployed
  - Public KOALA interworked

- Phase.1 GENIcloud Federation
  - Deploy GENIcloud node into KHU cloud
  - Interwork with Slice Manager at GIST for FiRST & PlanetLab federation

- Phase.2 FiRSTcloud Development for PlanetLab Federation
  - Design and develop OpenStack based PlanetLab federation [key contribution]
  - Interwork with Slice Manager at GIST for PlanetLab federation
  - Contribute enhanced software to OpenStack & PlanetLab

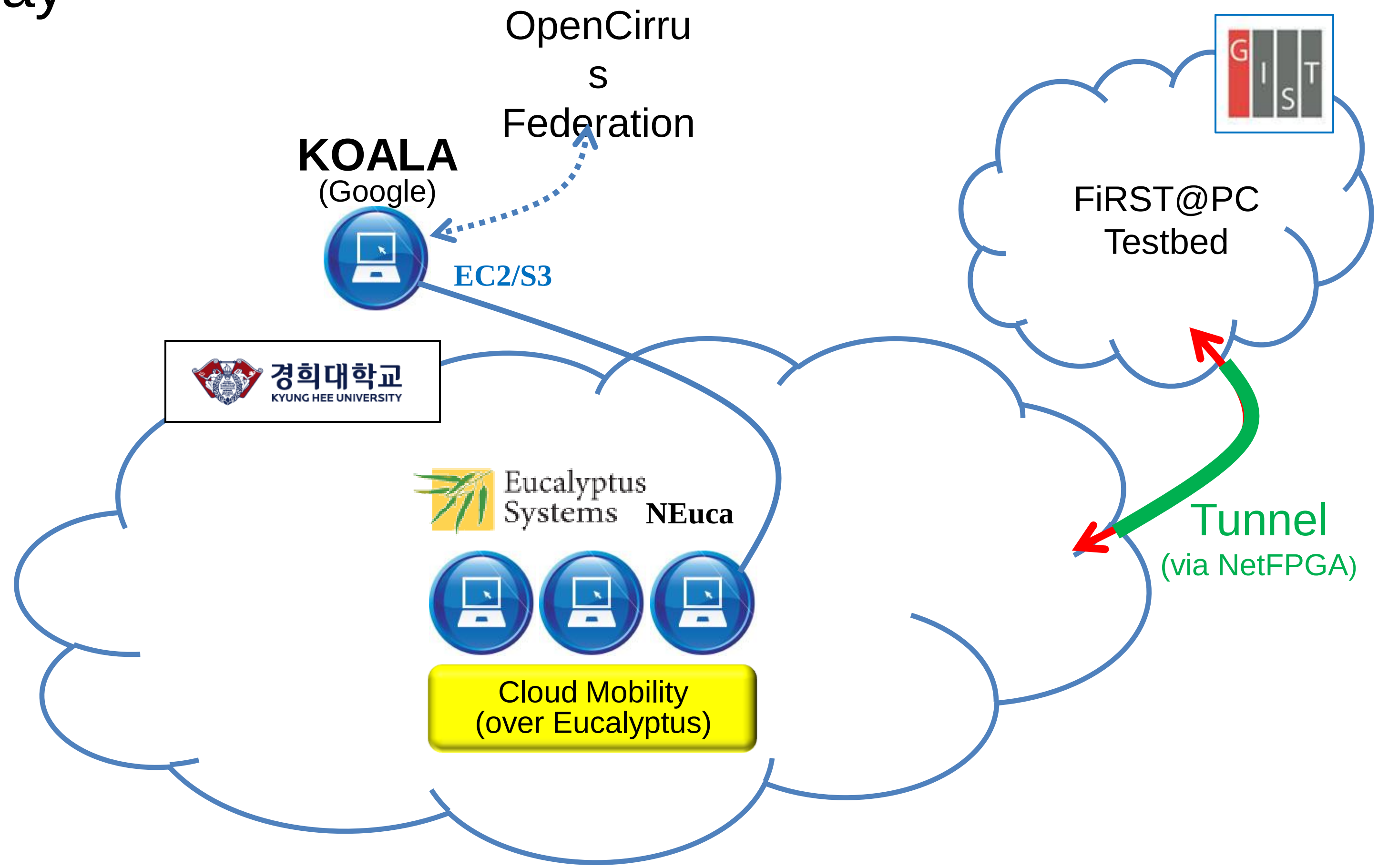
KHU Mobile Cloud Evolution

- Phase.3 Zero-client based Mobile Cloud Development
  - Revise “Cloud mobility (developed at 2010)” for OpenStack
  - Newly design and develop “Cloud aware Mobile node” [key contribution]
  - Enhance RFB protocol for wireless links [key contribution]
  - Contribute key contributions to OpenStack and Adnroid-x86.org

- Phase.4 FiRSTcloud Evolution for NaaS
  - Newly design and develop NaaS based on OpenStack:NaaS [key contribution]
    - Deploy OpenFlow/SoftRouter into private cloud and inter-cloud networking
  - Extends FiRSTcloud interface with Slice Manager for NaaS [key contribution]
  - Contribute key contributions to OpenStack and PlanetLab

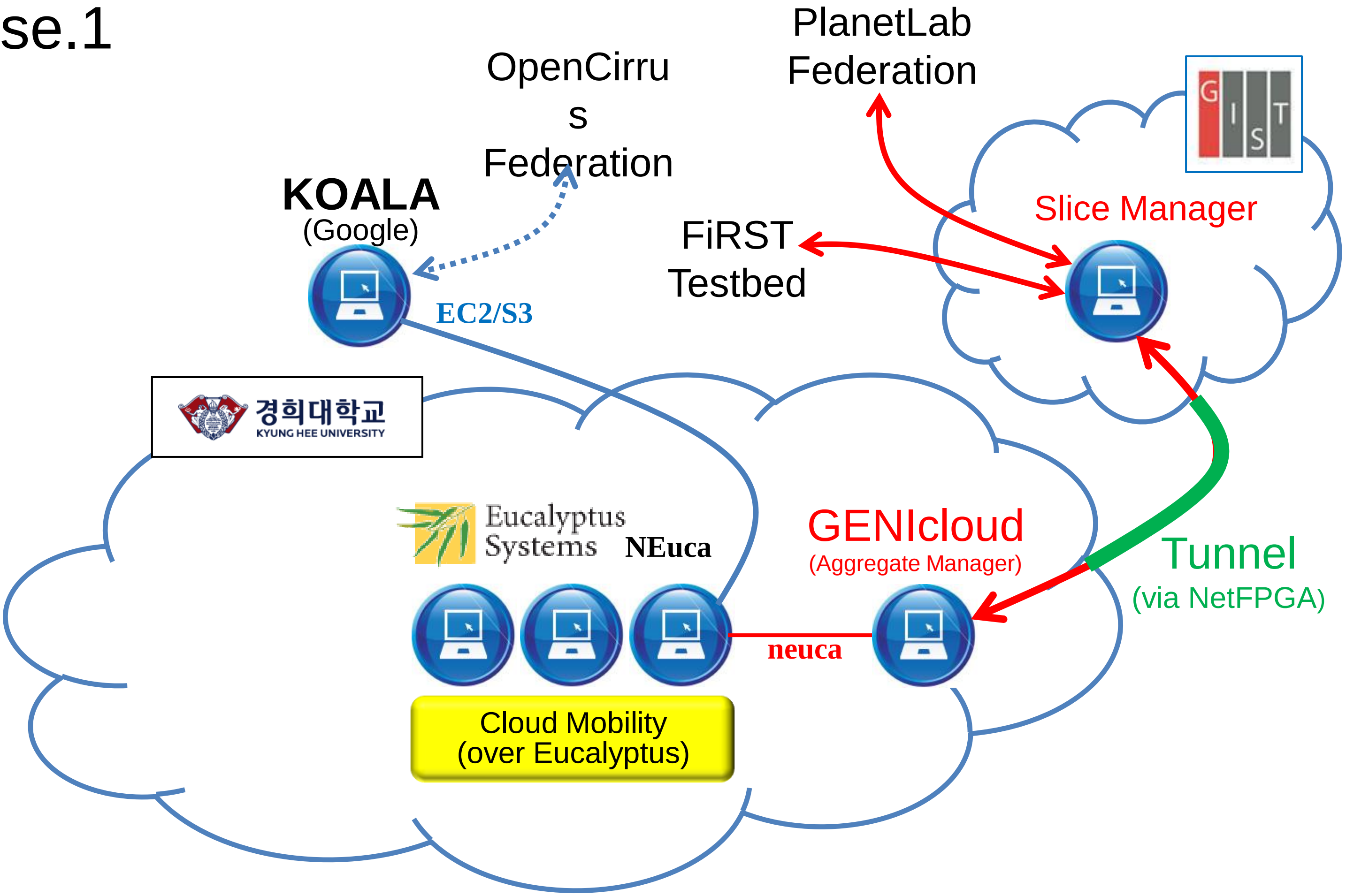
KHU Mobile Cloud Evolution

- Today



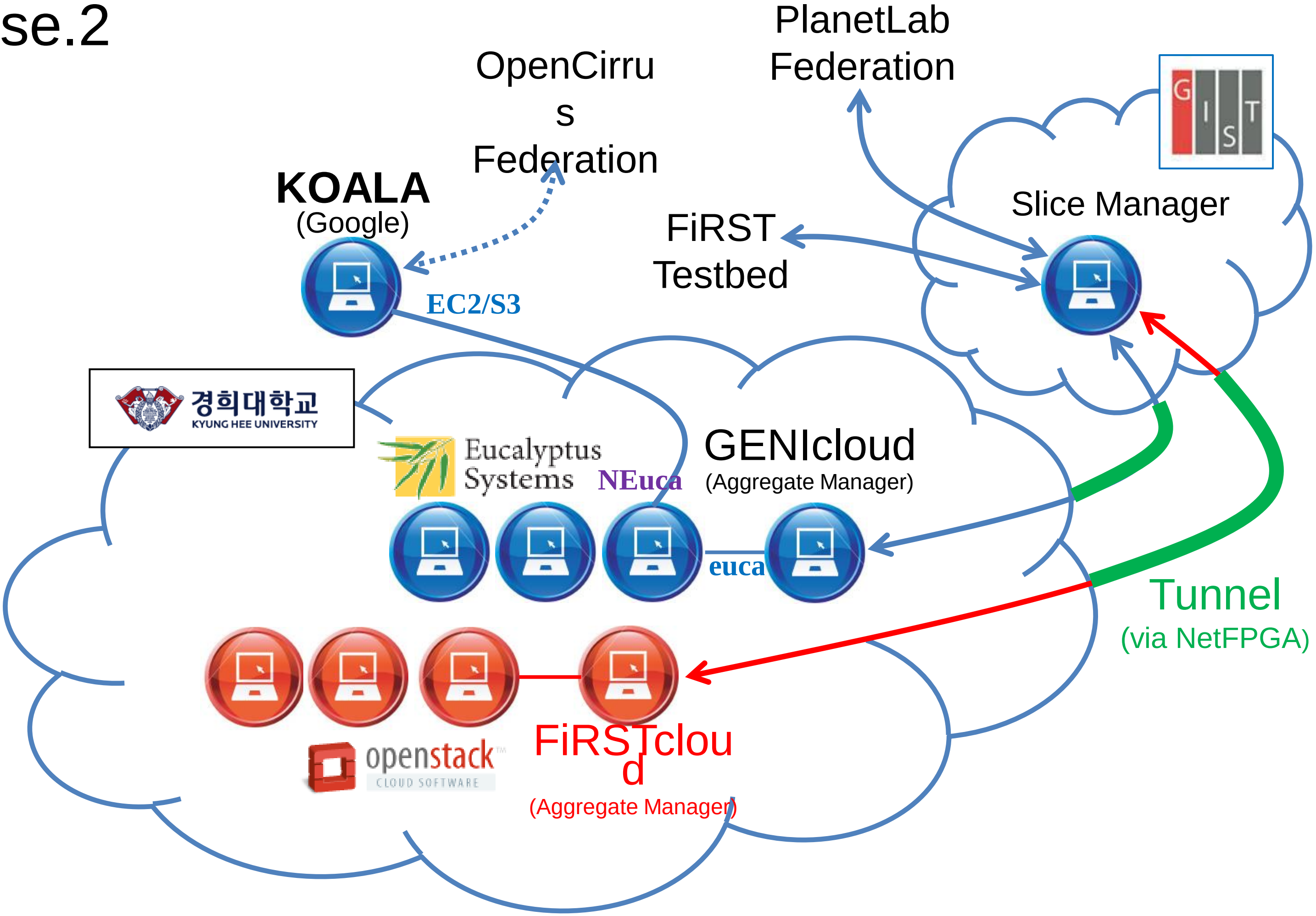
KHU Mobile Cloud Evolution

- Phase.1



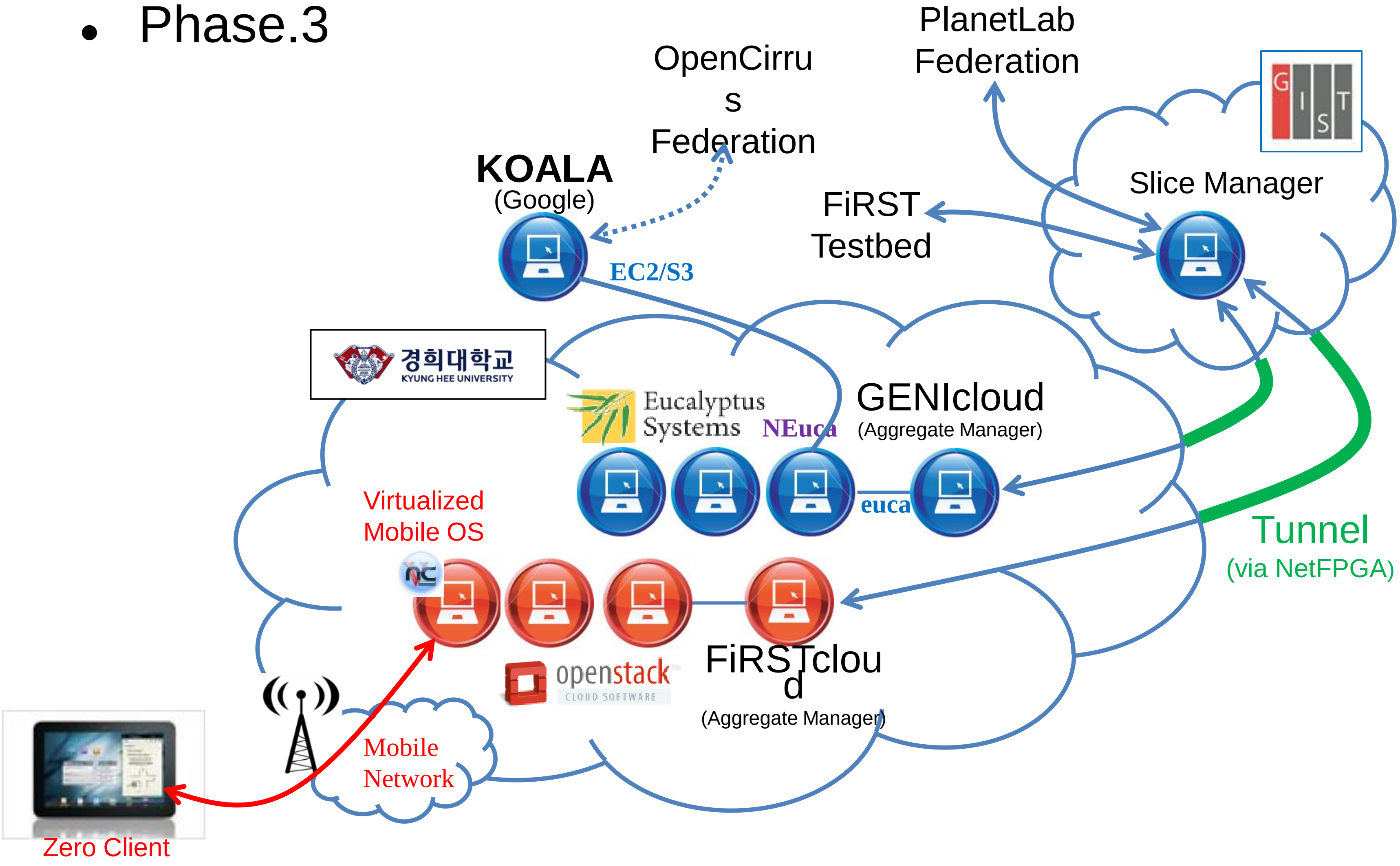
KHU Mobile Cloud Evolution

- Phase.2



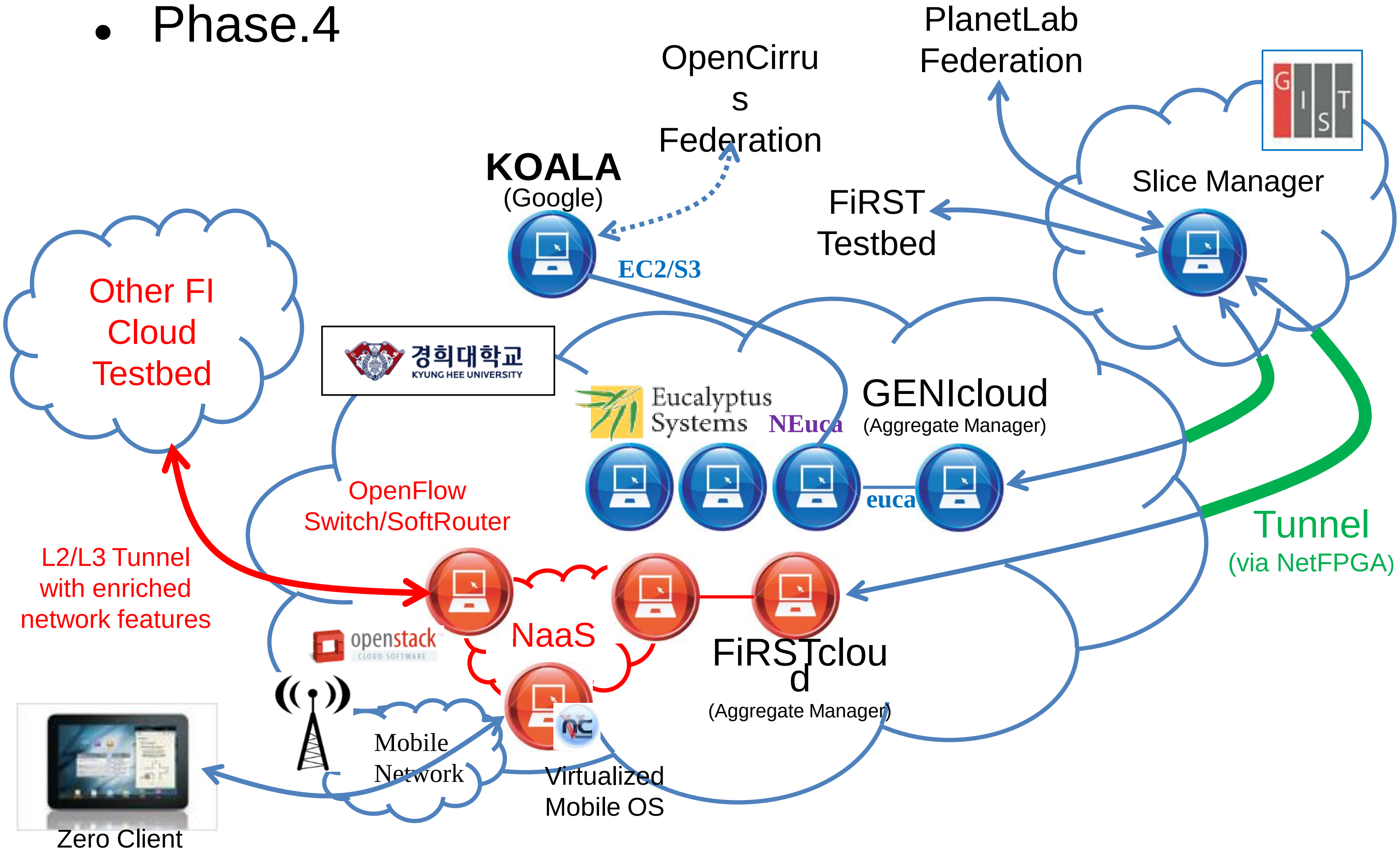
KHU Mobile Cloud Evolution

- Phase.3



KHU Mobile Cloud Evolution

- Phase.4


PlanetLab
Federation
OpenCirru
s
Federation
KOALA
(Google)
EC2/S3
FiRST
Testbed
Slice Manager
G I S T
Other FI
Cloud
Testbed
경희대학교
KYUNG HEE UNIVERSITY
Eucalyptus
Systems
NEuca
GENIcloud
(Aggregate Manager)
euca
OpenFlow
Switch/SoftRouter
Tunnel
(via NetFPGA)
L2/L3 Tunnel
with enriched
network features
openstack
CLOUD SOFTWARE
NaaS
FiRSTclou
d
(Aggregate Manager)
Mobile
Network
Virtualized
Mobile OS
Zero Client