NC STATE UNIVERSITY
Department of Computer Science

NICT National Institute of Information and Communications Technology

Service Offering Model and Versatile Network Resource Grooming for Optical Packet and Circuit Integrated Networks

Project Report
PI Meeting, Davis, CA, June 2014

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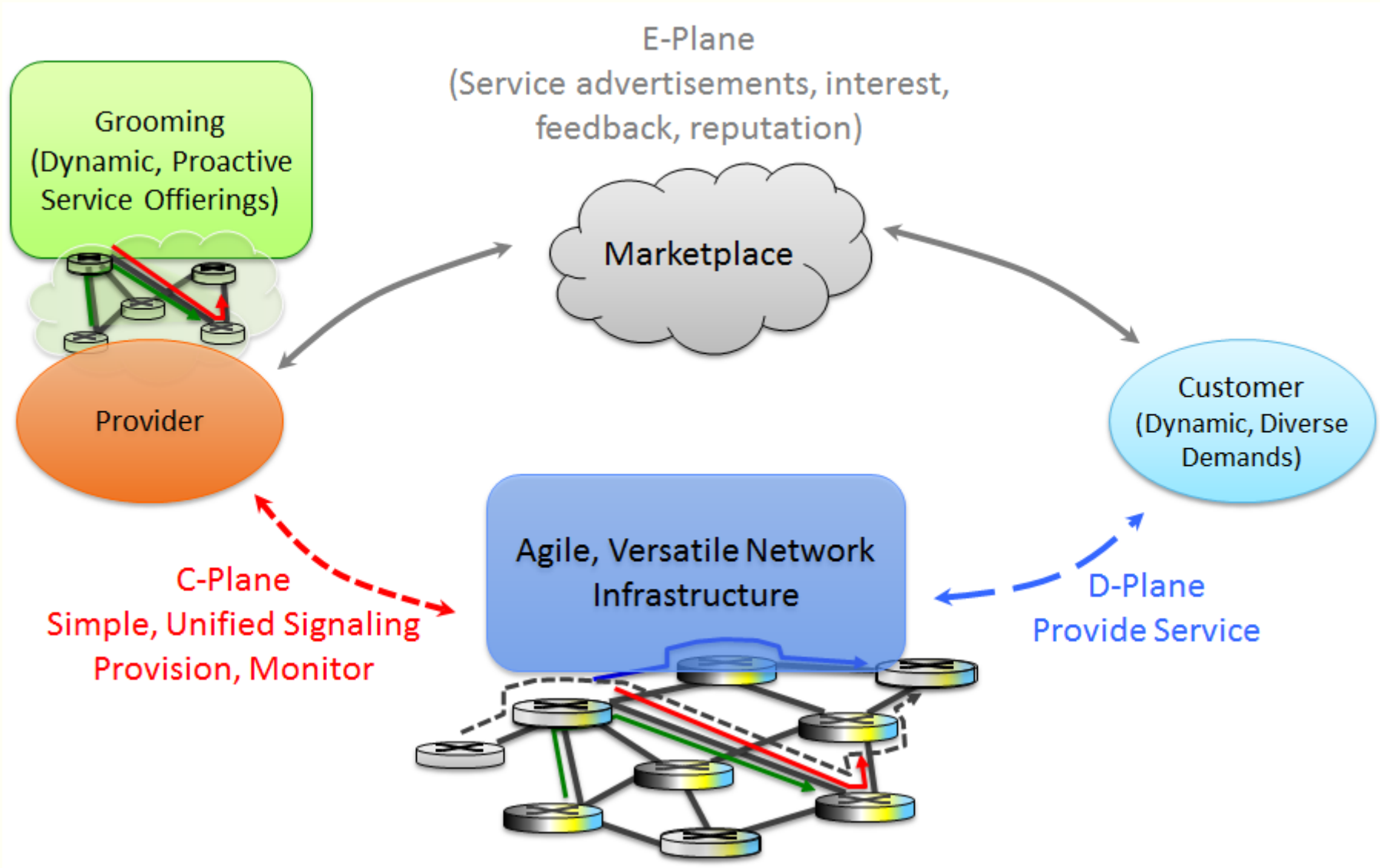
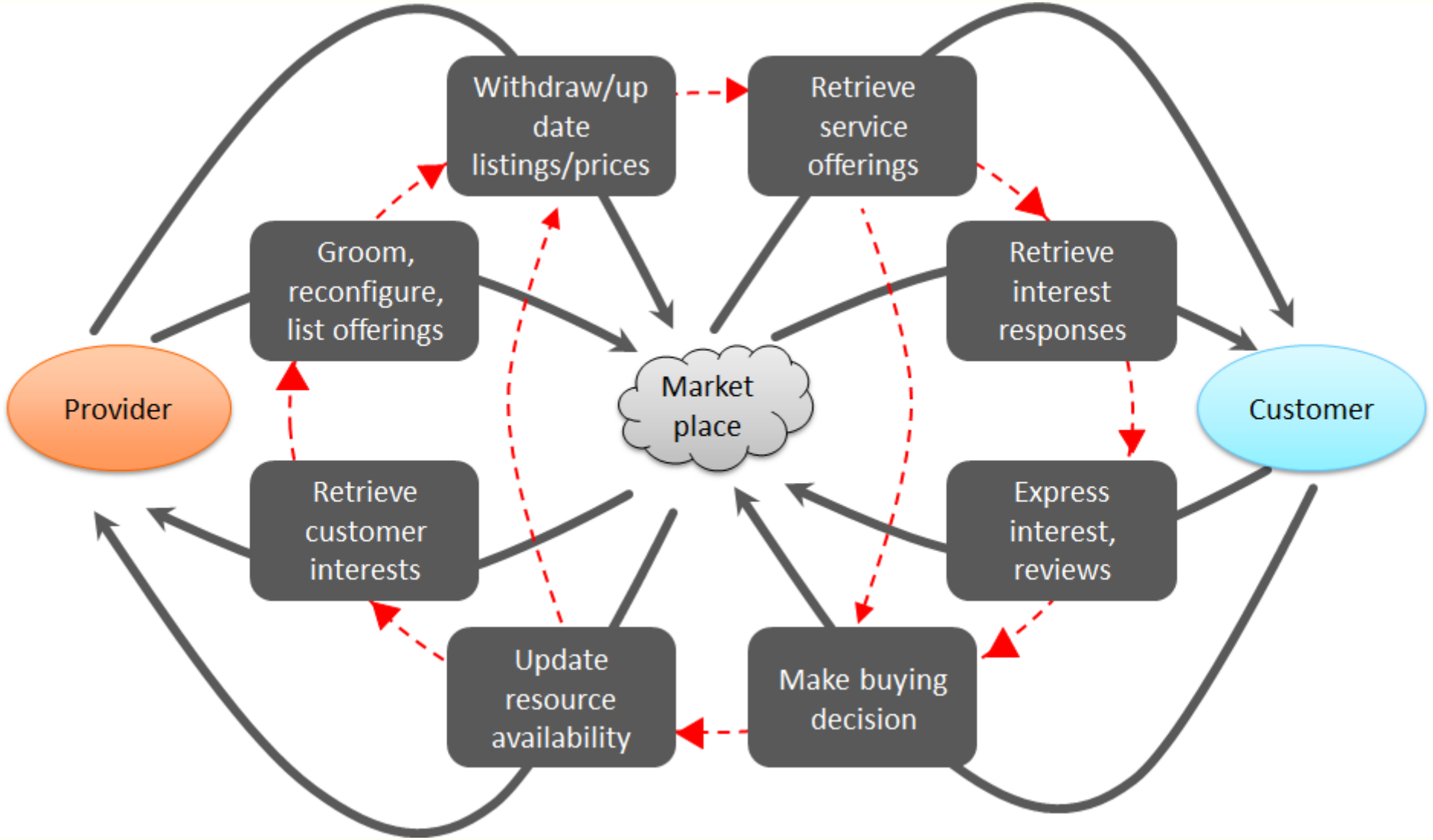
Overview of Project

- Enable customer-provider collaborative optimization of agile optical hybrid packet/circuit network
  - Existing OPCINet project: hybrid OPS/OCS switch (SDN or custom control plane)
  - Traffic grooming: mapping demands to available resources (for OPCINet, flexible resources)
  - Choice marketplace: rendezvous of capabilities and needs (Existing ChoiceNet project)
- Customer and provider each best know cost and value to themselves
- Rendezvous can achieve “demand-grooming” and “offering-grooming”

Overview of Project



Marketplace as Rendezvous



Existing Research / Technology

- ChoiceNet project
  - NSF FIA supported, in final year of project
  - Articulation of an architecture to enable choice as a mechanism to foster innovation in the Internet, along economic principles
- OPCINet project
  - A hybrid OPS/OCS optical switch
  - Complete data plane
  - Flexible control plane

Project Roadmap

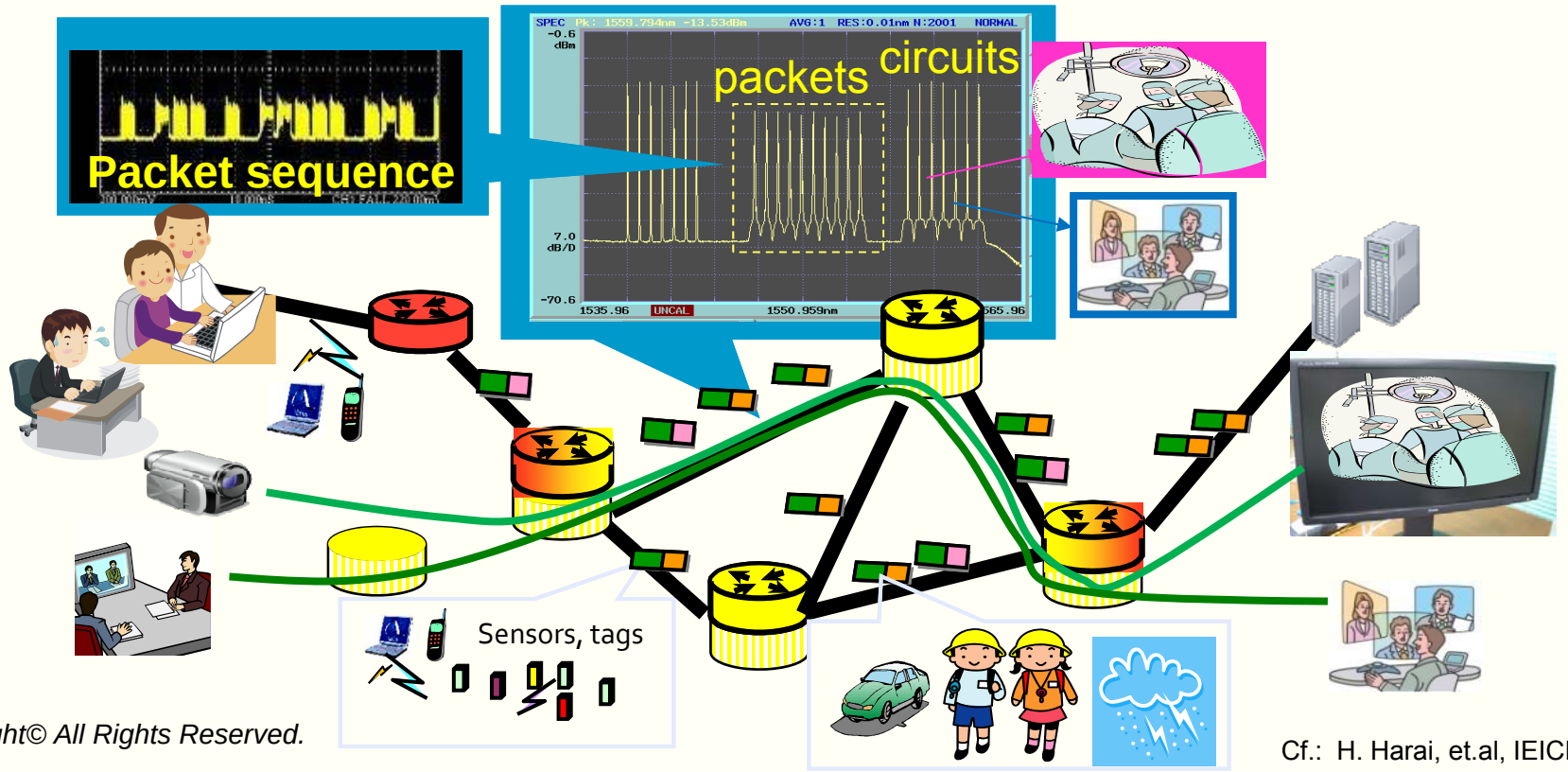
- Define detailed semantics for a choice-based marketplace for OPCINet-based network (ChoiceNet-like, but restricted and specialized)
- Design proactive grooming algorithms OCS/OPS dynamic allocation capable networks
- Integrated prototype
  - OPCINet control plane integration of choice marketplace APIs
  - Choice marketplace implementation
  - Integration of candidate grooming algorithms

Research Tasks

OPCINet - Concept -

Optical Packet & Circuit Integrated Network (OPCINet)

- User view: A "high-speed, inexpensive" service and "low delay, low data-loss" service on a single optical network
- Network provider view: Large switch capacity (>100Gbps Optical Packet), energy saving, and flexible & efficient resource use under a simple control

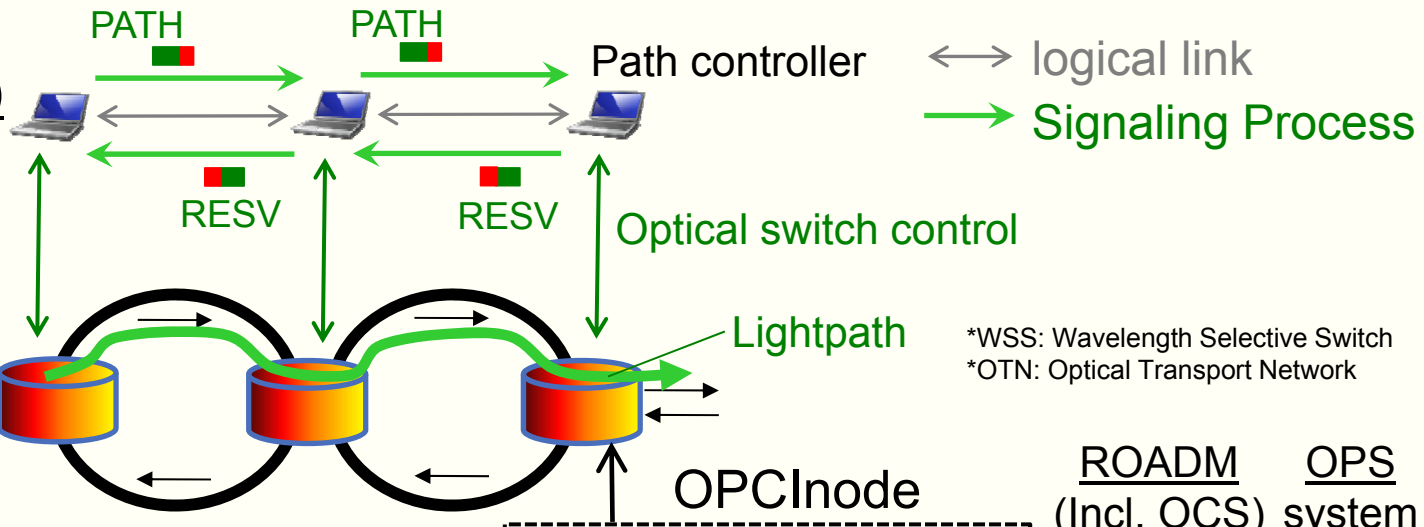


Cf.: H. Harai, et.al, IEICE Trans. on Commun., March 2012.

OPCINet - OPCInode and Switching -

Stable & Simultaneous transfer of lightpath signals and optical packets

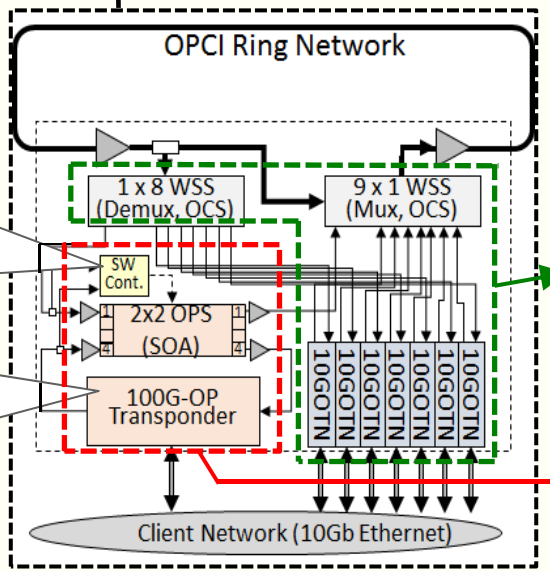
Optical Circuit Switching (OCS)



*WSS: Wavelength Selective Switch
*OTN: Optical Transport Network

Optical Packet Switching (OPS)

OPCInode



ROADM (Incl. OCS) OPS system

Switching Table

Label ID	Input port	Output port
0x01	4	1
0x02	4	1
0x03	1	4

10GbE←→100Gbps colored (10-λs) optical packet conversion

Label Mapping Table

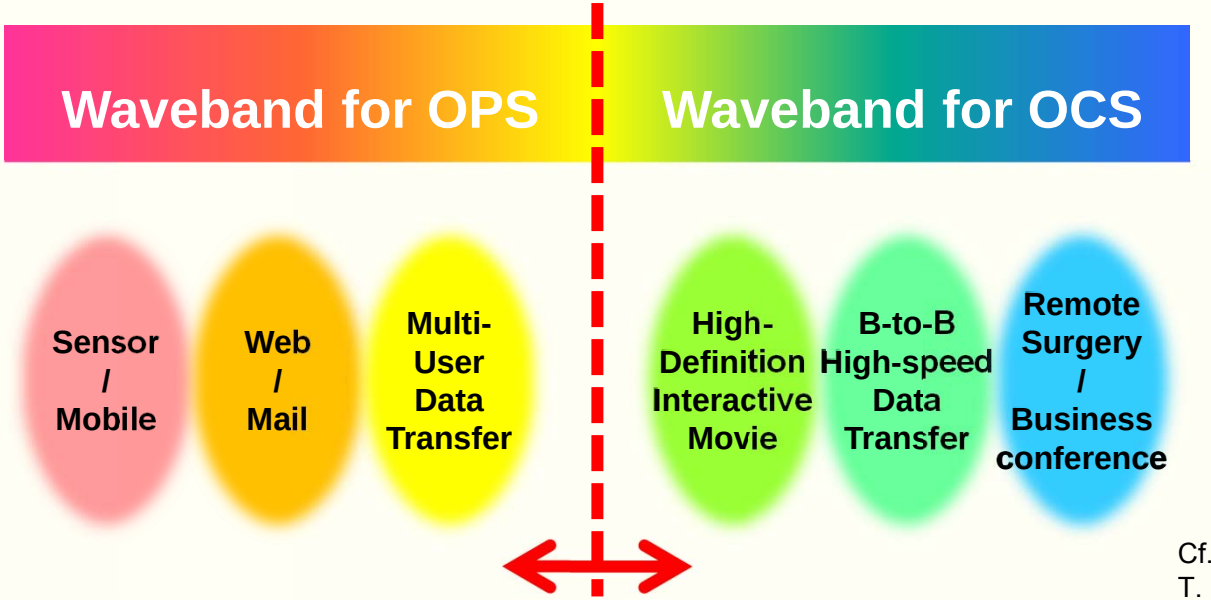
DEST IP address	Label ID
10.100.1.0/24	0x01
10.100.2.0/24	0x02

Cf.: H. Furukawa, et.al, *Optics Express*, Dec. 2011.

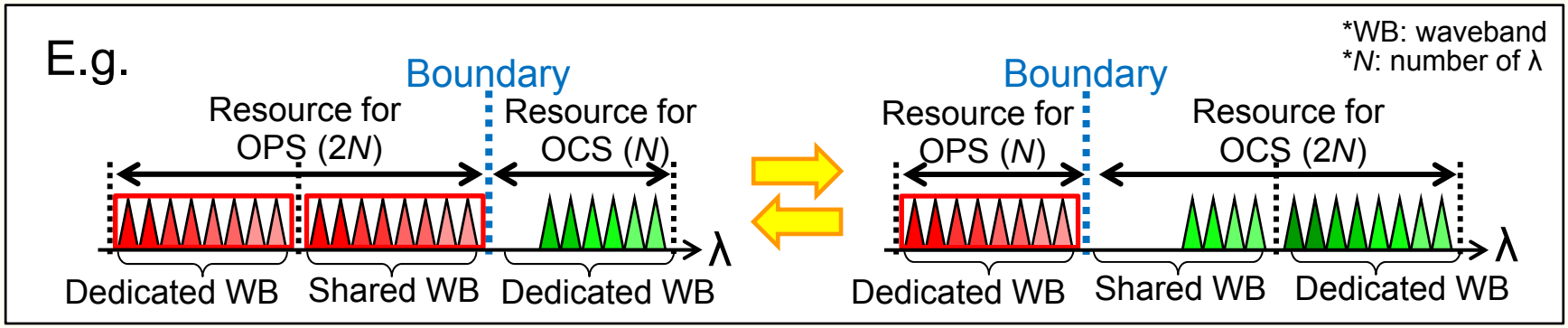
OPCINet - Dynamic Resource Allocations -

Dynamic Resource Allocations (DRA) to OPS/OCS:

Movable boundary to separate OCS- and OPS-resources



Cf.:
T. Miyazawa, et. al., JOCN, Jan. 2012.
H. Furukawa, et.al, *Optics Express*, Jan. 2014.

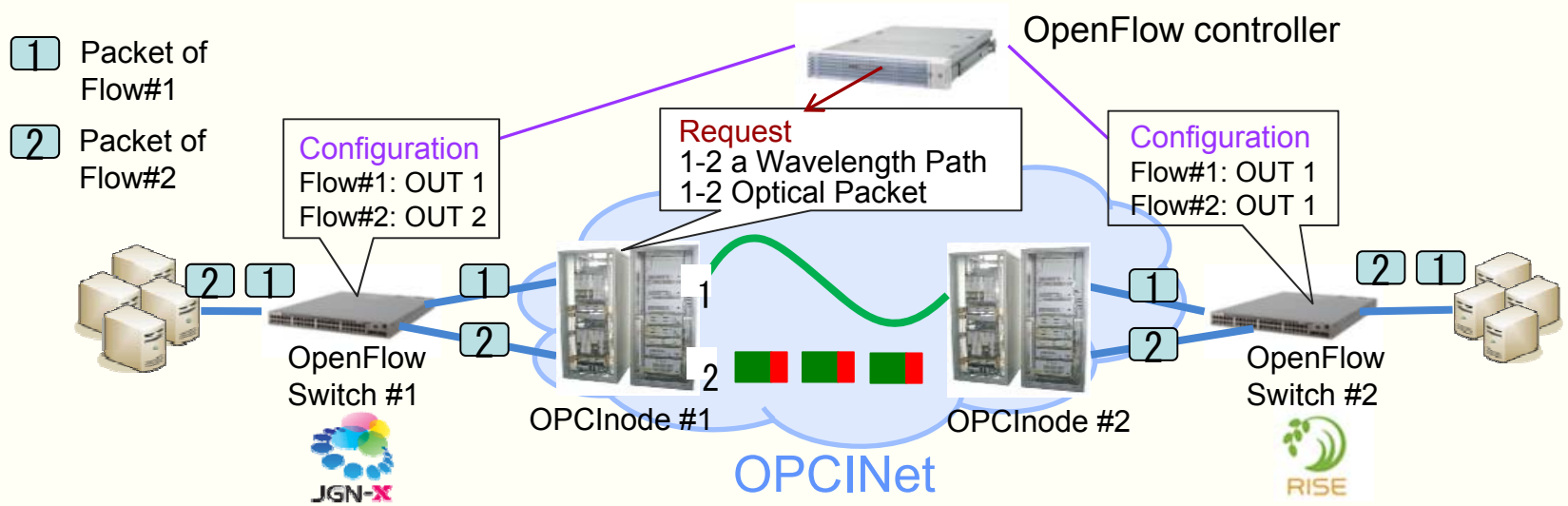


OPCINet - SDN -

Optical SDN (Software Defined Networking):

“Centralized OpenFlow” × “Distributed OPCInode” Interworking

- Edge Net or Data-Center Net requests routes with required quality information
- OPCI Net sets up appropriate path routes or packet routing tables



No.	Time	Source	Destination	Protocol	Info	
1	0.000000	172.18.0.1	172.18.0.2	ICMP	Echo (ping) request	26.3 ms
2	0.026304	172.18.0.2	172.18.0.1	ICMP	Echo (ping) reply	
3	1.000465	172.18.0.1	172.18.0.2	ICMP	Echo (ping) request	1.9 ms
4	1.002329	172.18.0.2	172.18.0.1	ICMP	Echo (ping) reply	
5	2.001429	172.18.0.1	172.18.0.2	ICMP	Echo (ping) request	1.9 ms
6	2.003361	172.18.0.2	172.18.0.1	ICMP	Echo (ping) reply	
7	3.001393	172.18.0.1	172.18.0.2	ICMP	Echo (ping) request	1.9 ms
8	3.003269	172.18.0.2	172.18.0.1	ICMP	Echo (ping) reply	

Path Route

No.	Time	Source	Destination	Protocol	Info	
1	0.000000	172.17.0.1	172.17.0.2	ICMP	Echo (ping) request	31.0 ms
2	0.031020	172.17.0.2	172.17.0.1	ICMP	Echo (ping) reply	
3	1.000241	172.17.0.1	172.17.0.2	ICMP	Echo (ping) request	1.7 ms
4	1.001909	172.17.0.2	172.17.0.1	ICMP	Echo (ping) reply	
5	2.000206	172.17.0.1	172.17.0.2	ICMP	Echo (ping) request	1.6 ms
6	2.001817	172.17.0.2	172.17.0.1	ICMP	Echo (ping) reply	
7	3.000171	172.17.0.1	172.17.0.2	ICMP	Echo (ping) request	1.6 ms
8	3.001727	172.17.0.2	172.17.0.1	ICMP	Echo (ping) reply	1.6 ms

Packet Route

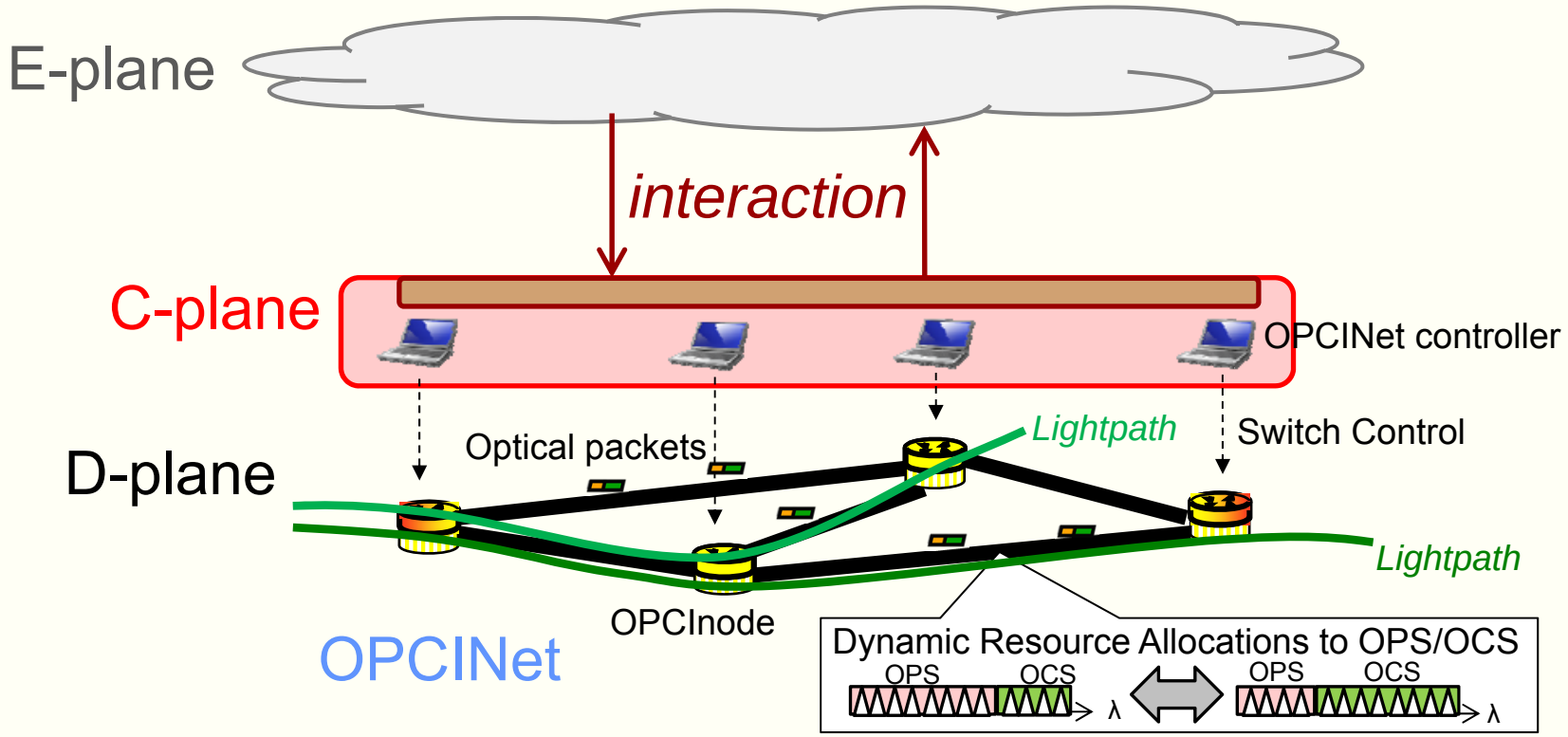
T. Miyazawa et al., SDN Workshop at IEEE Globecom 2013.

Rudra Dutta, Takaya Miyazawa, "Service Offering and Grooming for OPCINet", JUNO PI meeting, UC Davis, CA, June, 2014

OPCINet - Research Tasks 1/2 -

Research Tasks in Japan side

- Control Interface on C-plane to interact with E-plane
- Integration/connection into OPCINet equipment, JGN-X, GENI



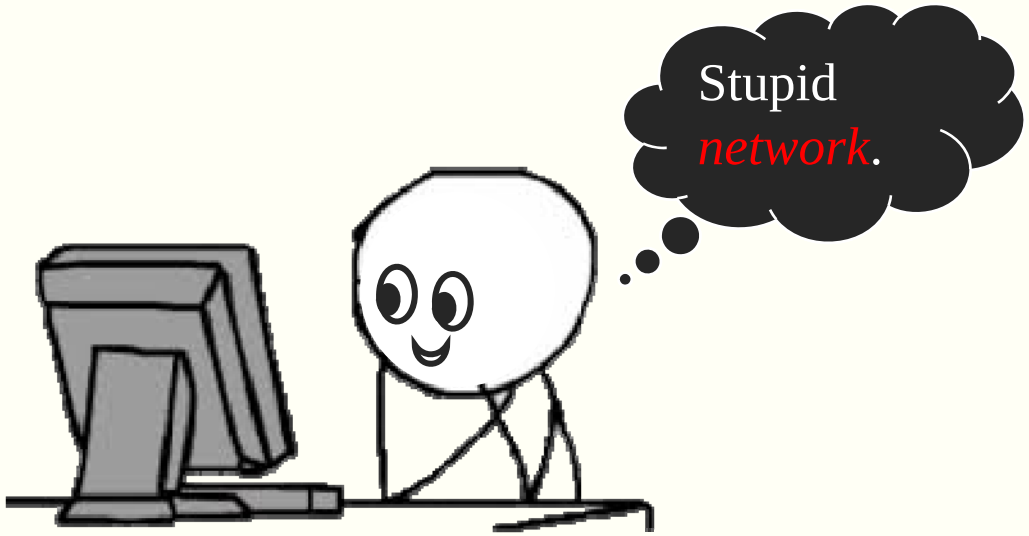
OPCINet - Research Tasks 2/2 -

Undisclosed

Choice Generation and Enablement

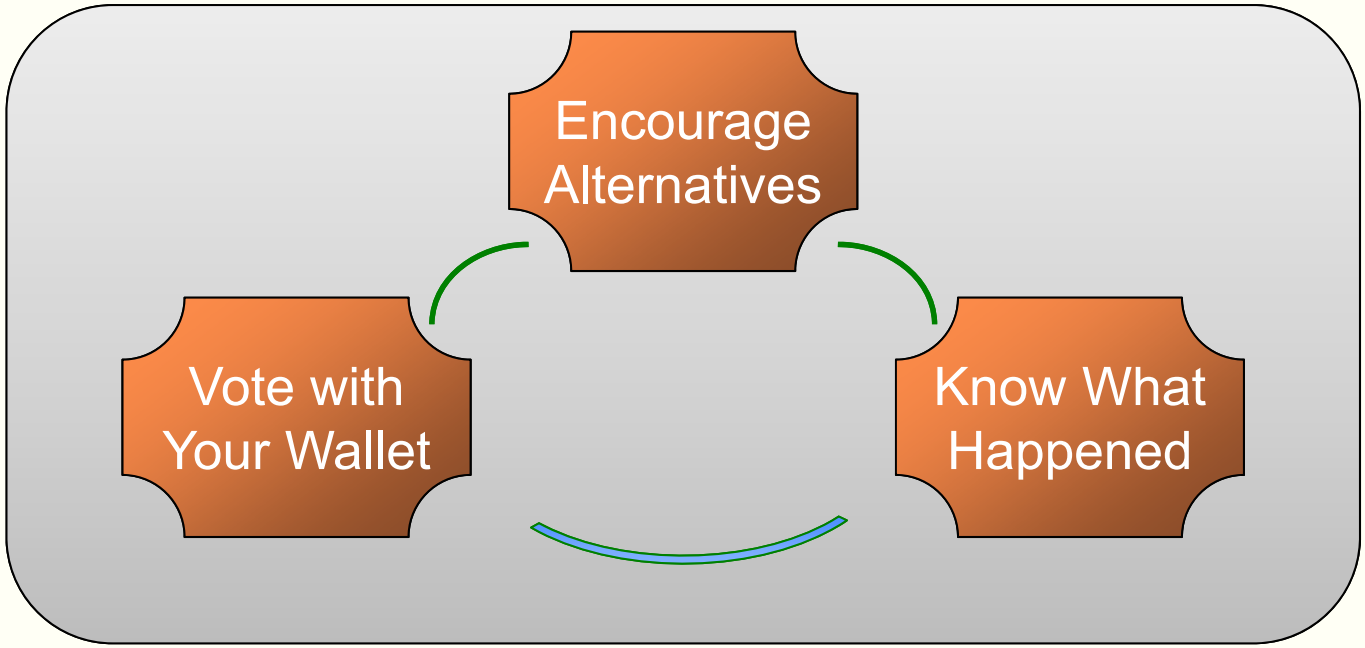
- Generation
  - Traffic grooming, proactive grooming
  - Research focus of US-side team
- Enablement
  - Integration of grooming model with control plane
  - Presentation of choices to customers, purchase, tokens to link E-plane and D-plane
  - Reuse ChoiceNet semantics
  - Custom (simplified) specific implementation

Performance Woes



- Informed exercise of choice (backed by money) can reward providers with good performance
- Select for helpful providers, beneficial ecosystem

Architectural Need



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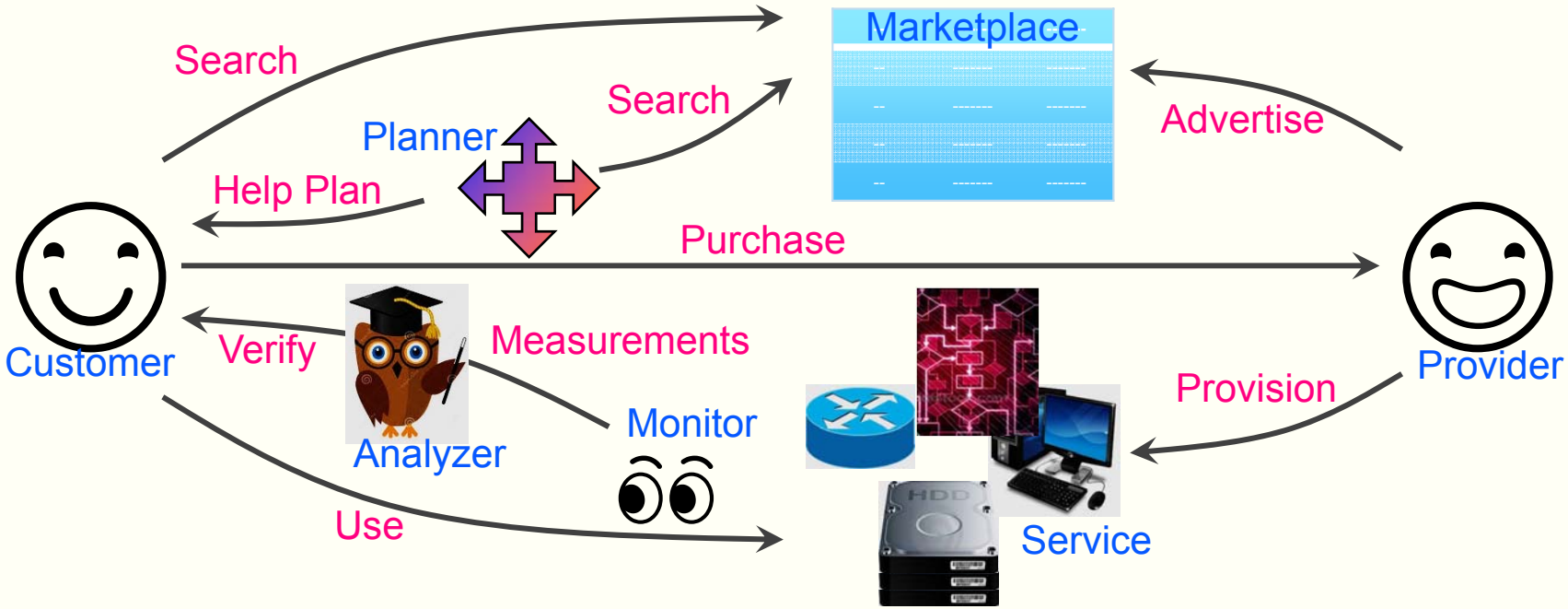
ChoiceNet Entities / Interactions

- Consumer – willing to exchange consideration for services deemed of value
  - User who exercises choice → “chuser”

- Provider – provides services in exchange of consideration
  - HW/SW infrastructure provider (path service)
  - Marketplace provider
  - Composition provider
  - Verification provider

Entities and Interactions



- Informed exercise of choice (backed by money) can reward providers with good performance
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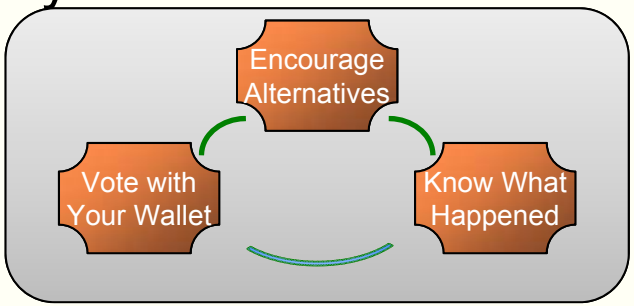
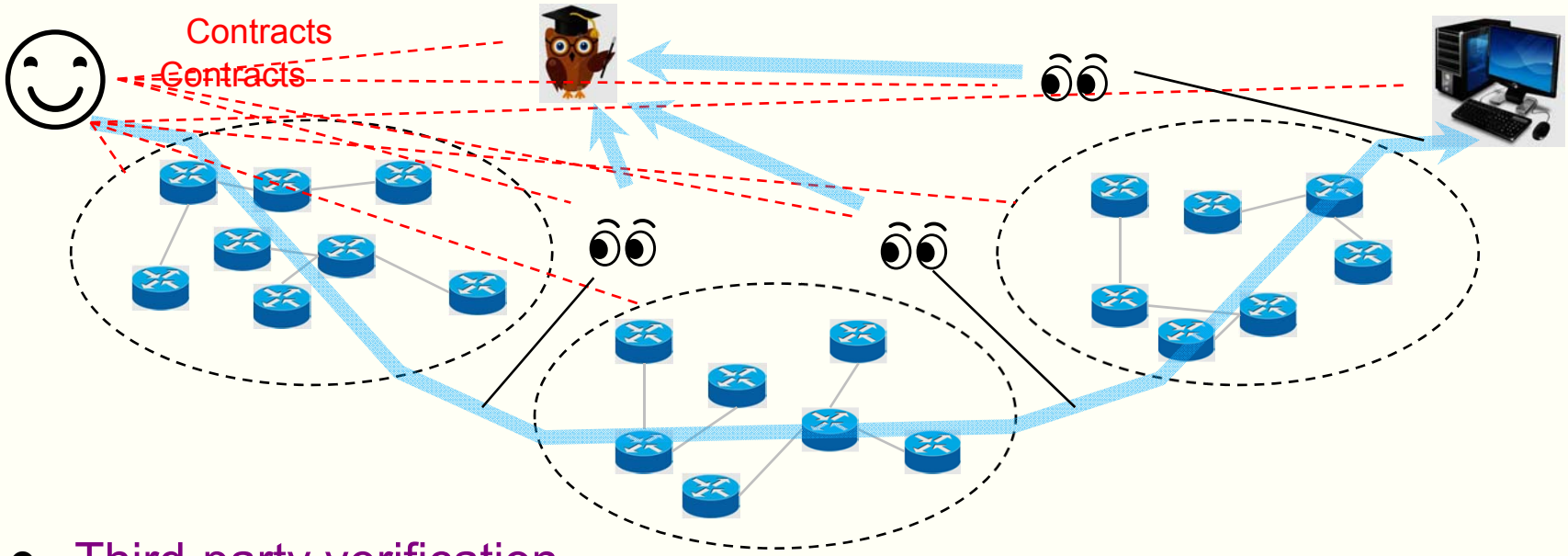


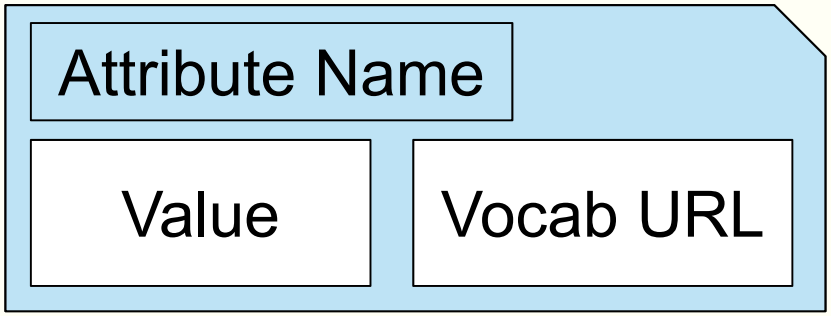
Per-Provider Contracts



- Third-party verification
- A possible measurement service: timestamp marker packets
  - Packets recognized by flow, and shim header inserted by companion code at source
  - Can be split off, not necessarily in-flight at wire-speed
- GENI and NS-3 prototypes

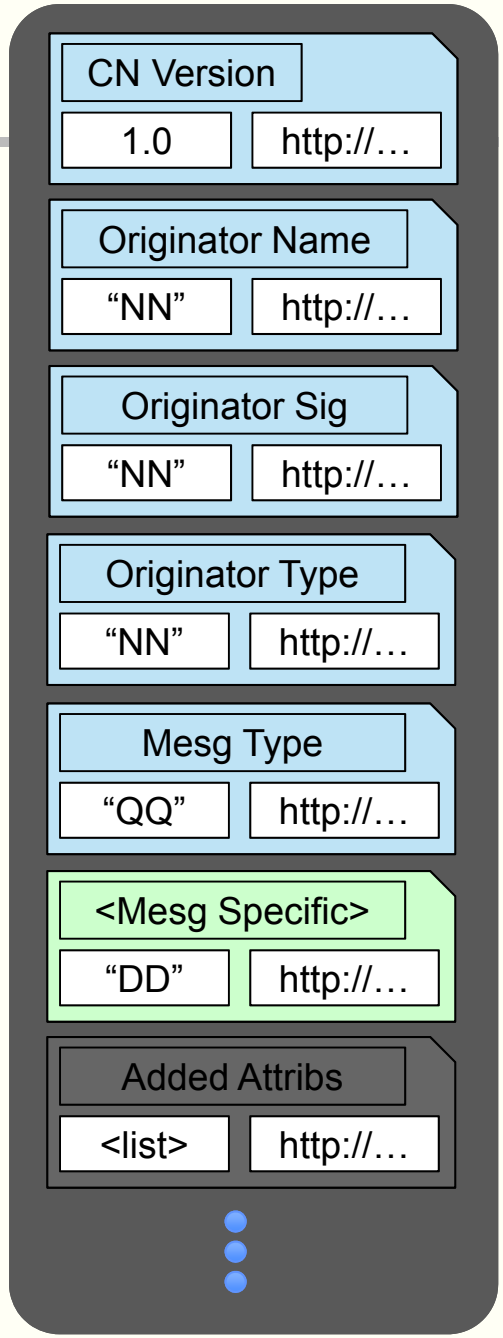
ChoiceNet Message Fields

- Attribute/Value/URL triple Convention
- Attribute
  - Must use a word from current vocabulary
- Value
  - Numerical value, OR URL for full value, OR another message field
- URL
  - Location of authoritative definition of vocabulary for “value”
  - Where you can go to download , if you don’t have it
  - ICANN URLs, for ChoiceNet “standard” vocabulary; others, for custom extensions (likely NULL for numeric)



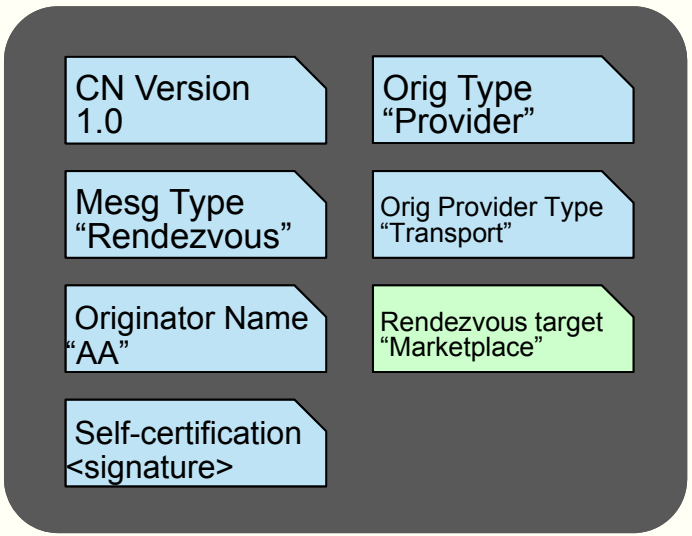
ChoiceNet Message Structure

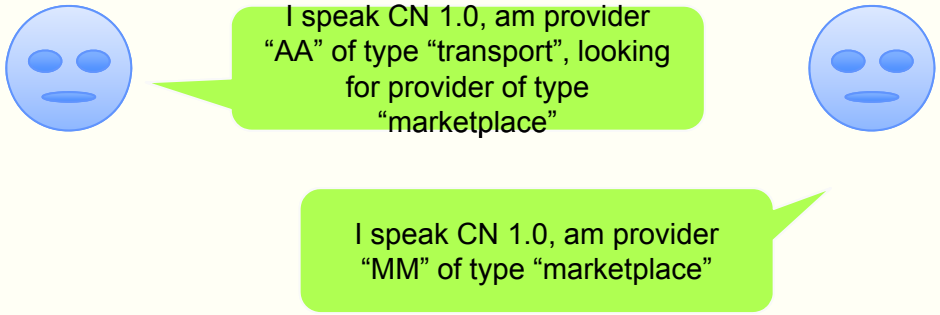
- ALL ChoiceNet messages follow same basic structure, which is hierarchical
  - Version and message type must exist
  - Originator name, signature, type must exist
  - Additional fields appropriate (expected) for message type
  - Values of some fields may be other sets of fields
  - Special field to list remaining attribute fields (of this level)
  - Expected in this order, but order may not matter
- Semantics expressed in some appropriate syntax
- Encapsulated in some appropriate transport with corresponding addressing (IPv4, UDP, … IPv6?)
  - (“There are many ChoiceNets”)



ChoiceNet Rendezvous Message

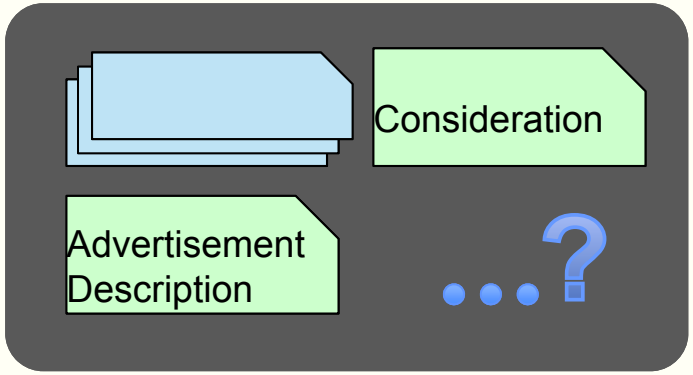
- ChoiceNet vocab version/URL
- Identify originator, originator entity type, provider type (if entity type is provider)
  - Desired provider type to rendezvous with
  - Request response



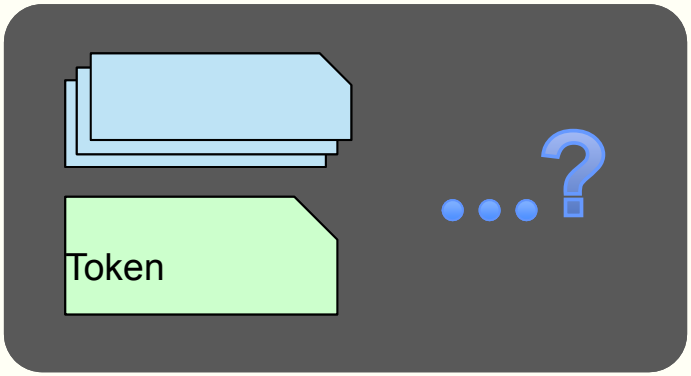


Advertisements

Request to List

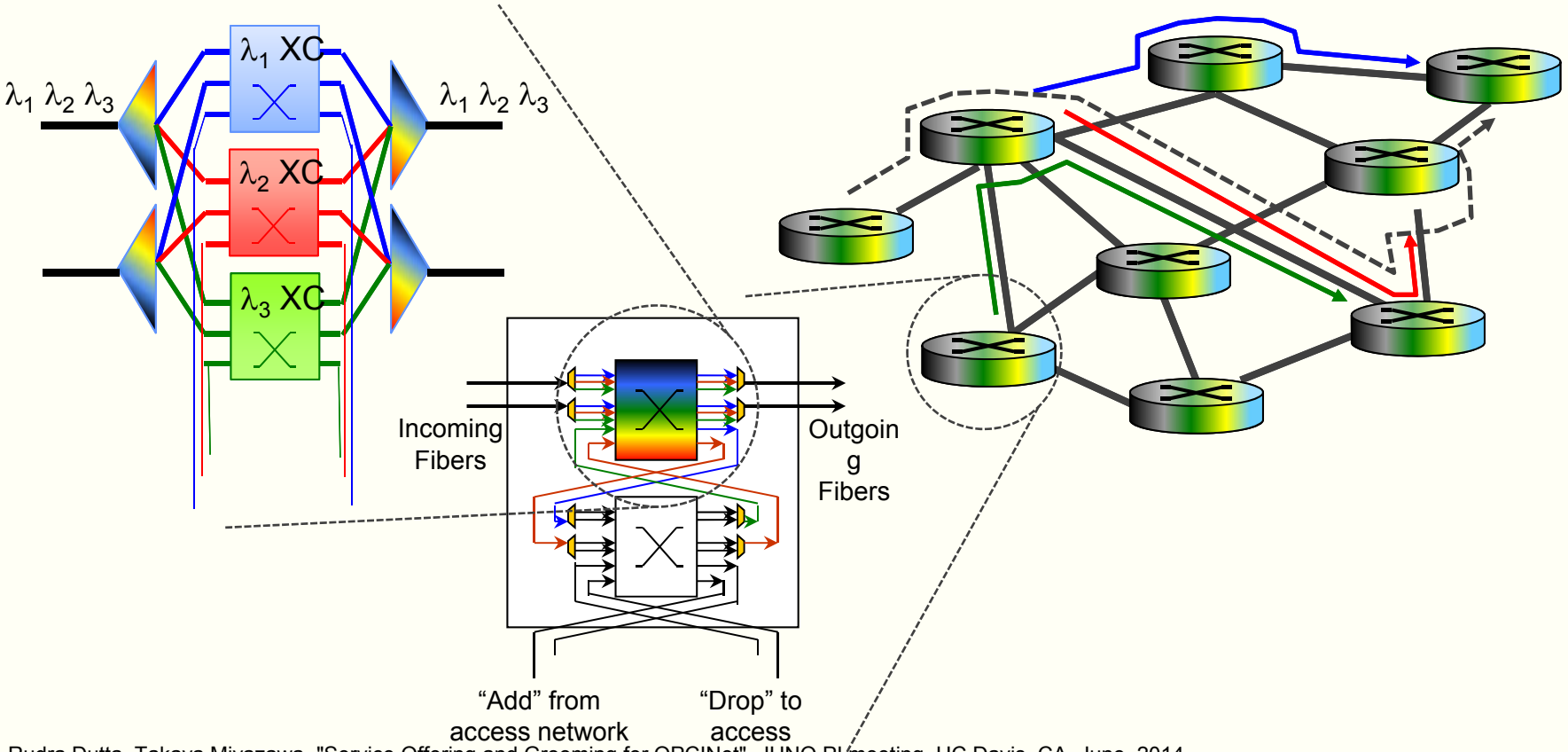


Listing confirmation



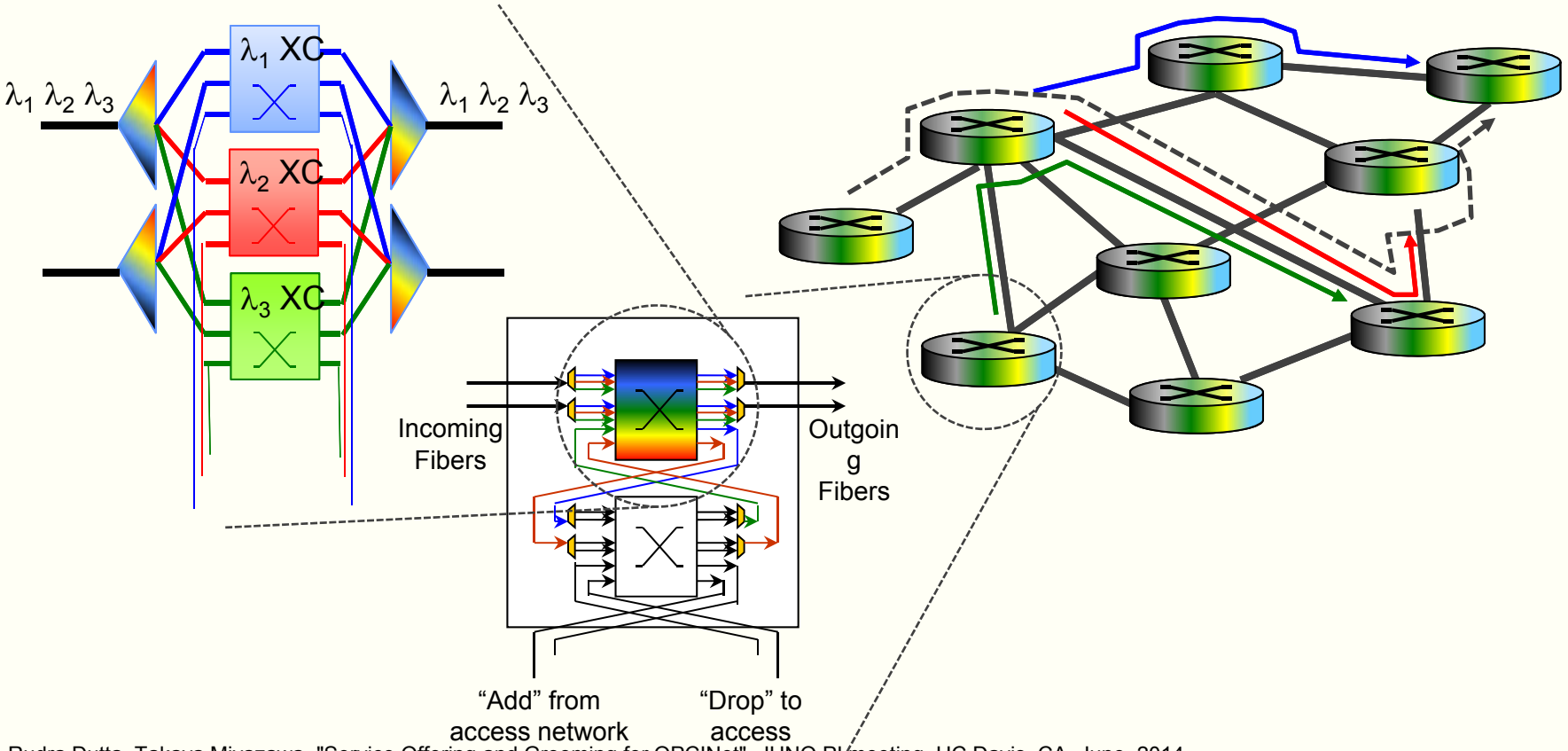
Traffic Grooming

- Classical definition → narrow
  - OEO minimization
  - Multiplexing lower rates into wavelengths



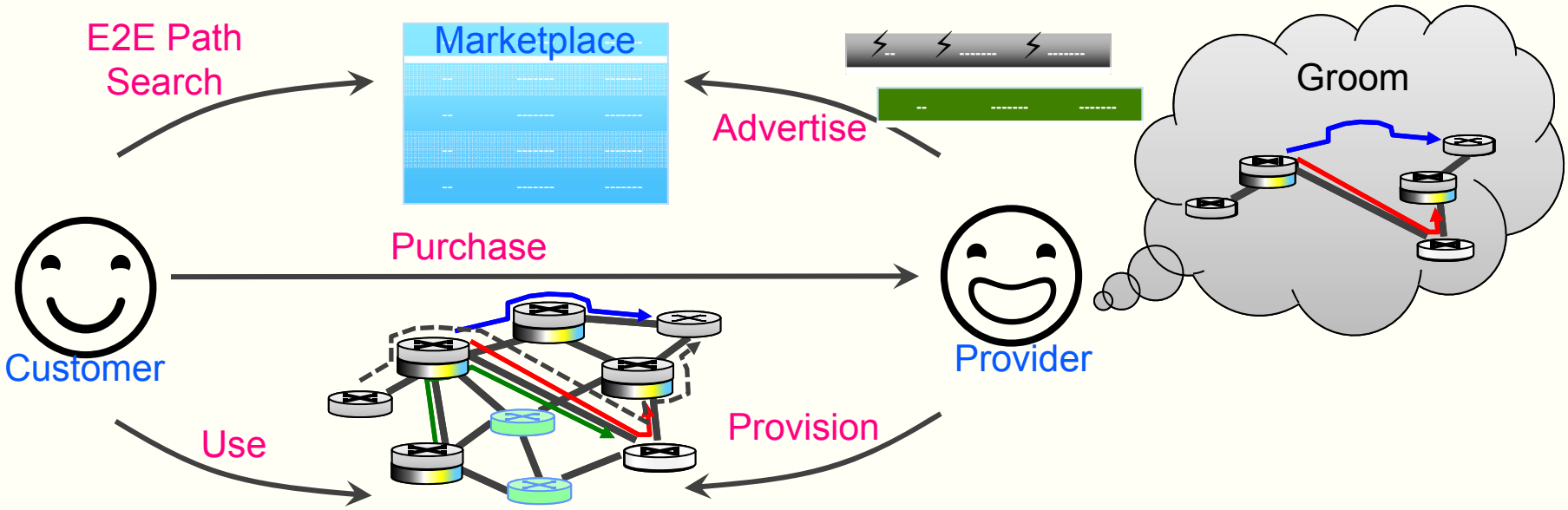
Traffic Grooming

- Broader definition
  - The art and science of converging available technologies of core and access for network-wide mutual benefit



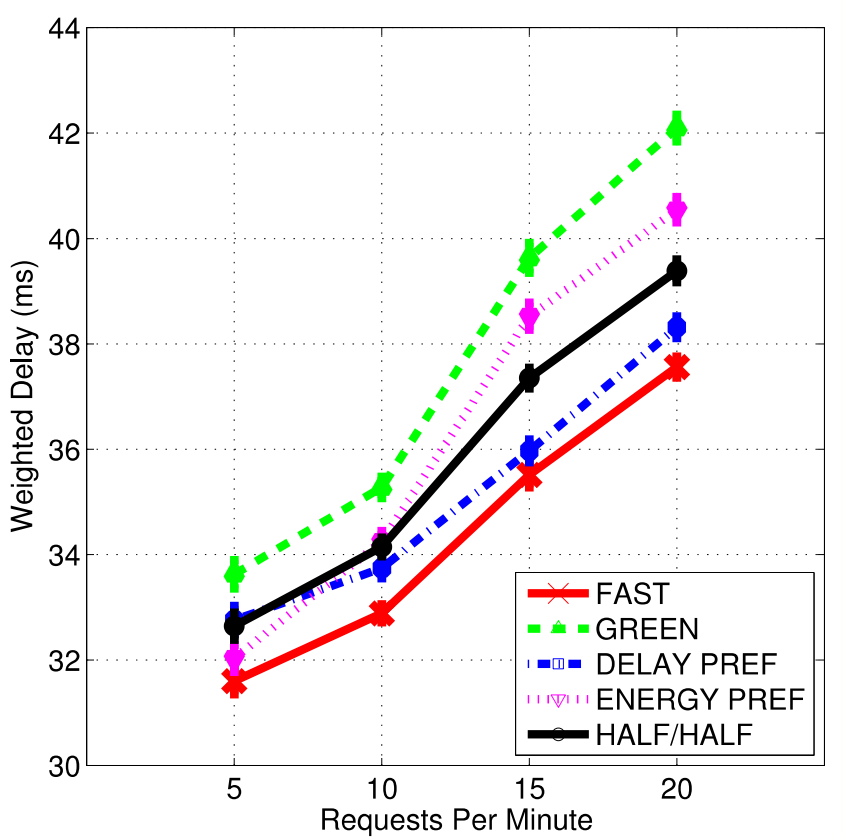
Rudra Dutta, Takaya Miyazawa, "Service Offering and Grooming for OPCINet", JUNO PI meeting, UC Davis, CA, June, 2014

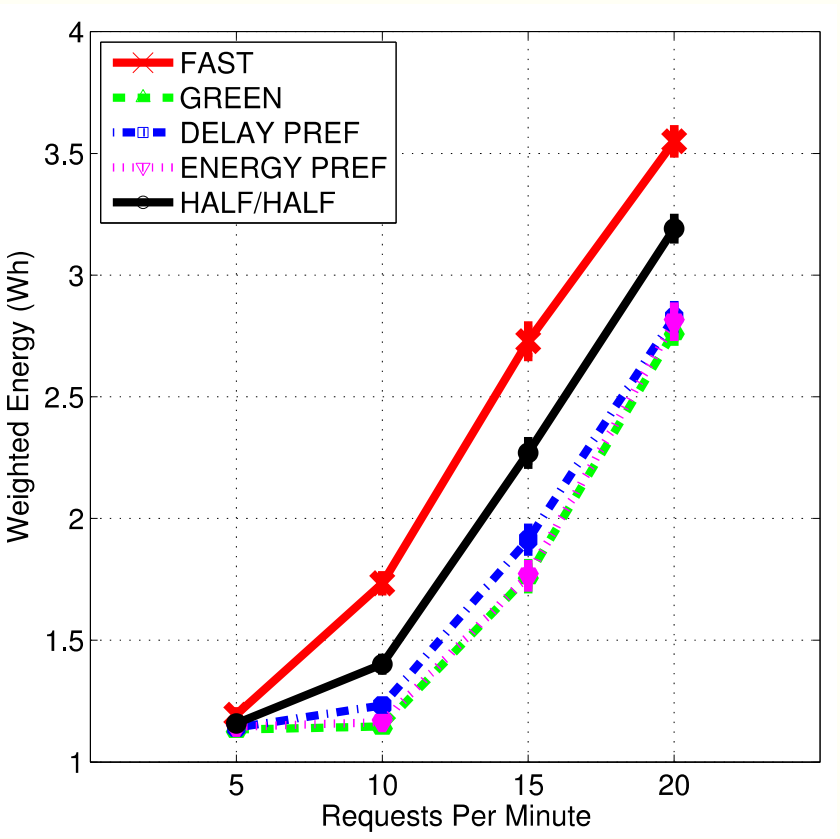
Providing Choice



- Provider provides two alternatives for every (potential) connection request: FAST (least delay); GREEN (least power)
- Customer strategies
  - FAST, GREEN, DELAY-PREF, ENERGY-PREF, HALF
- Simulations on NSFNET, USNET
- A C Babaoglu, S Huang, R Dutta

The Impact of Choice





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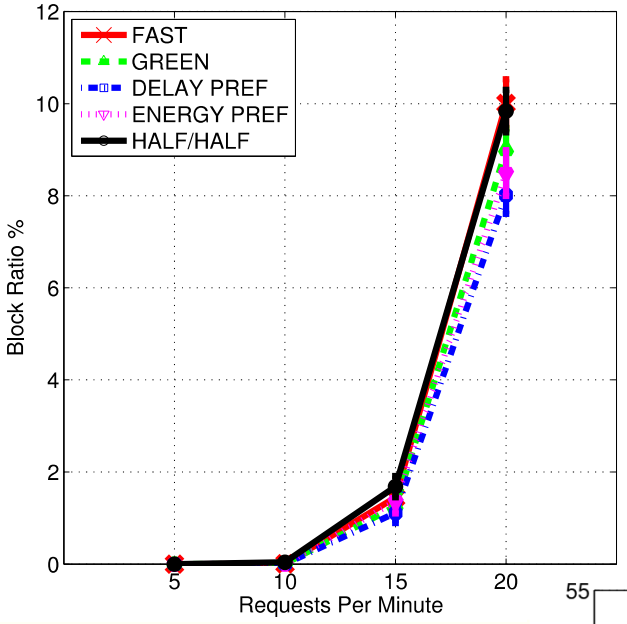

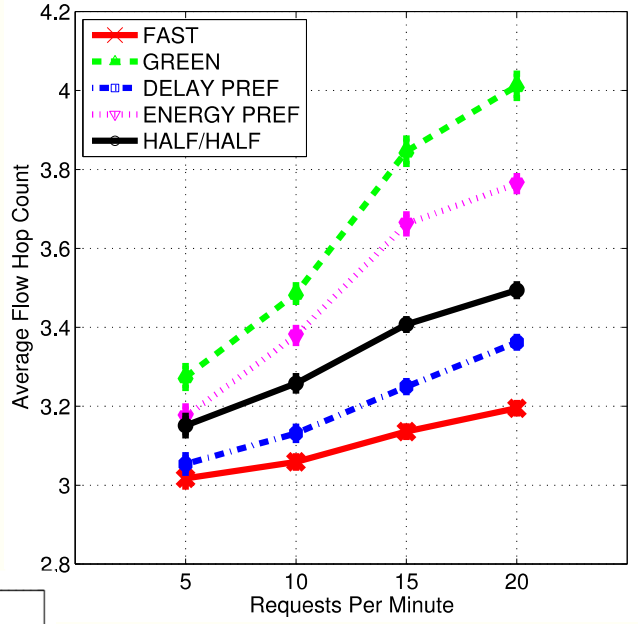

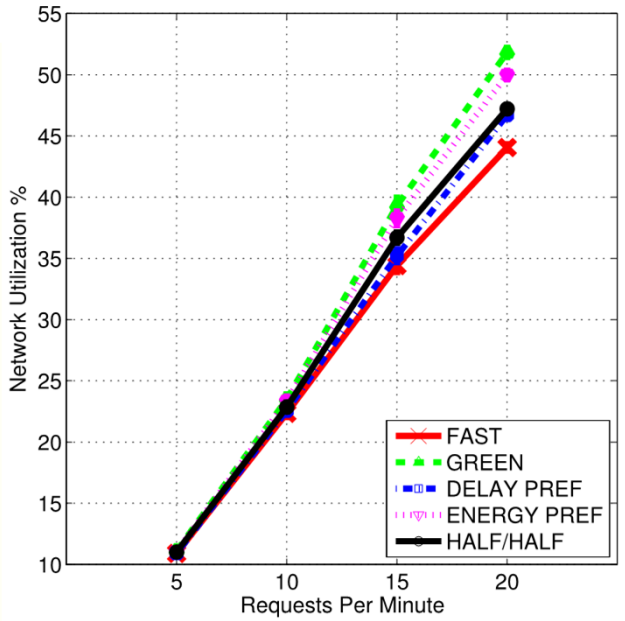

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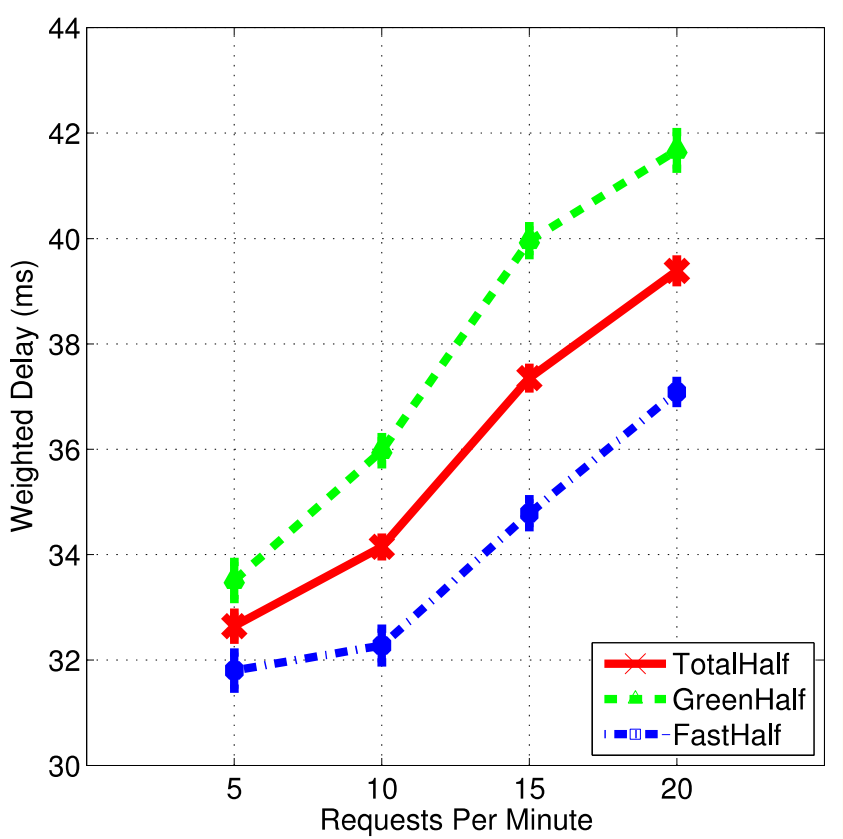
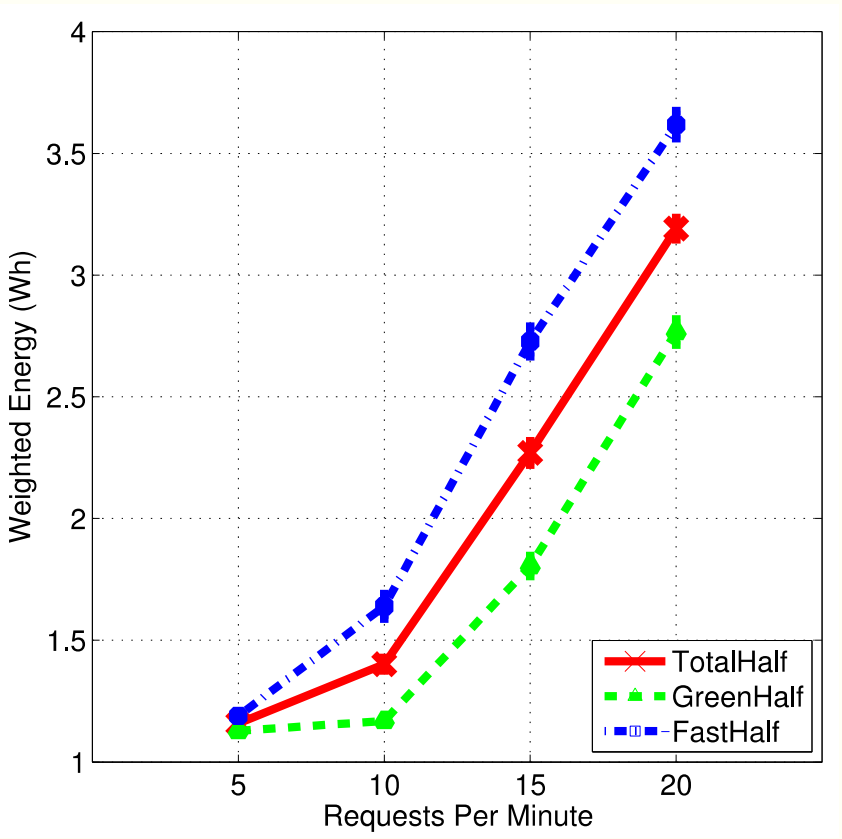
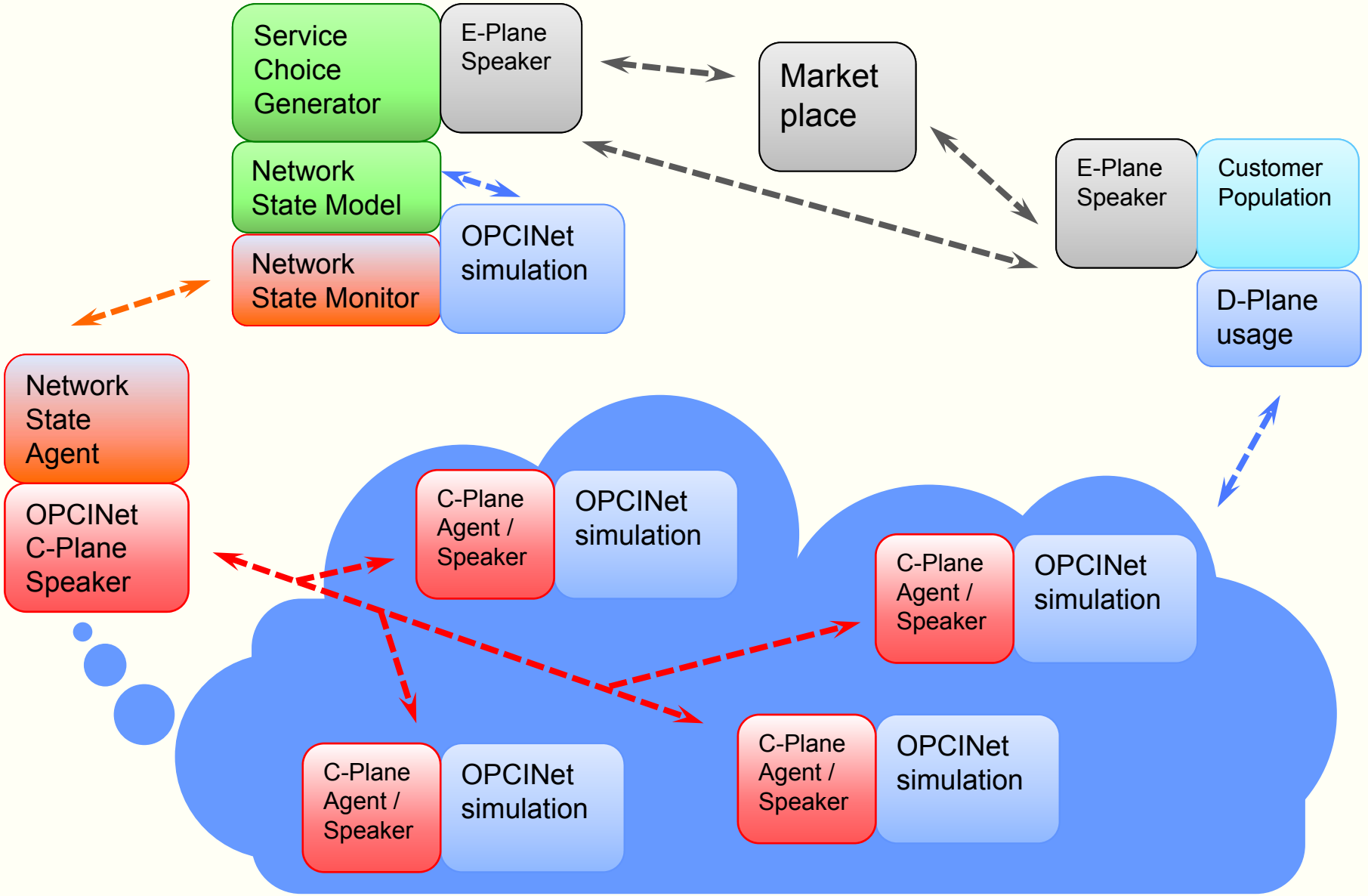




Prototyping

- OPCINet data plane and control plane are proprietary
  - JGN-X integration will use real OPCINet equipment (already connected)
  - Open prototype on GENI will need to use shell representing simulated OPCINet network (may use only control plane representative)
- New APIs and code developed through this project, either side, will be open-source
  - Control plane plugin code will be proprietary extension of OPCINet control plane
- Prototype 0 (workflow articulation), 1 (interfaces finalized, 2 (practical improvement)

Early Prototyping



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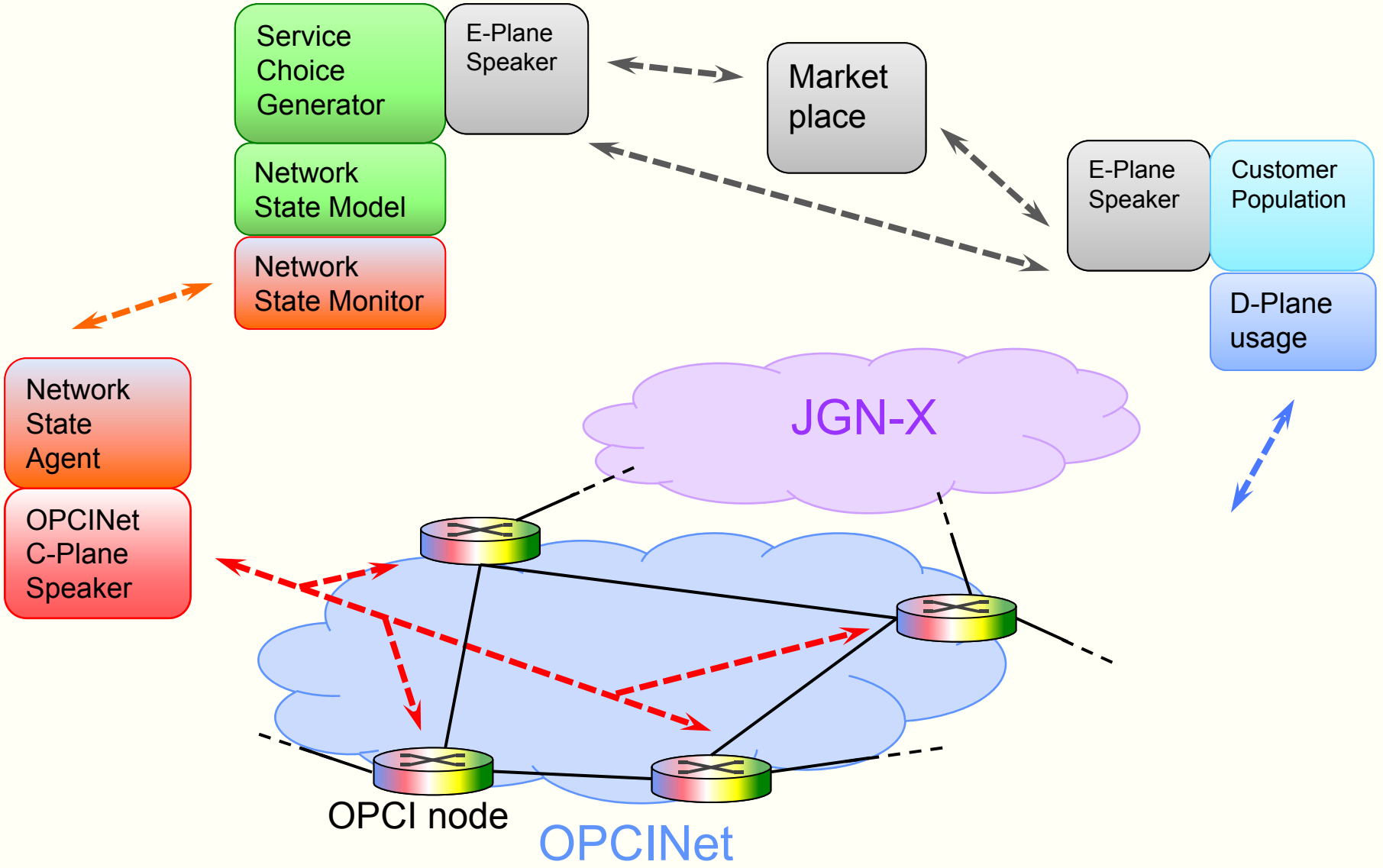
Prototyping – JGN-X & OPCINet



Facilities

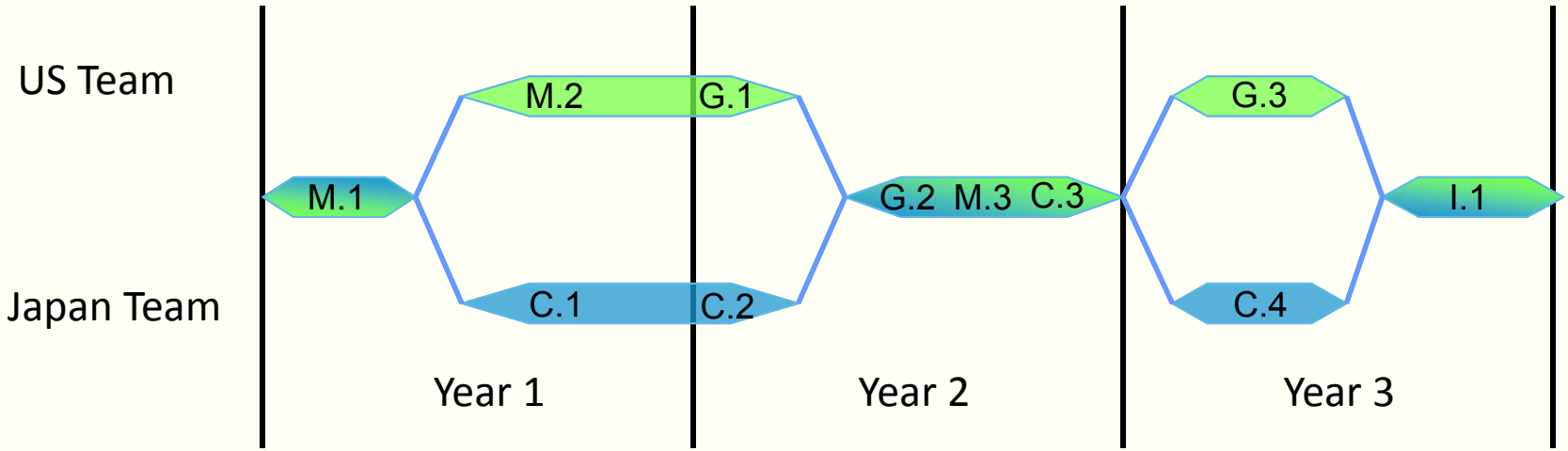
- NCSU and NICT teams have appropriate computing and lab/datacenter facilities on campus
- NCSU team has high-speed network access and access to GENI
- NICT team has access to JGN-X

Project Management

- US- and Japan-side PIs respectively lead their teams
- US PI serves performs overall project coordination
- Jointly responsible for integration, reporting, attendance at PI meetings, dissemination
- Alternating periods of {coupled but concurrent effort} and {closely working together}
- Currently in close collaboration phase – NICT PI visited NCSU lab and team earlier in June, 2014
- Monthly video conference, common repository, annual working meetings

Timeline

Undisclosed



Questions

Network Service Demand Evolution

- Optical substrates and backbones lie at the core of almost all planetary communications
- Internet, mobile internet, mobile content access, form increasingly significant part of it
- Large short-fuse file transfers form significant part of it
- Larger range of bandwidth needs
- More diverse timescales
- Desire for more buying options, green options

Network Service Offering Evolution

- Different backdrop in different countries
  - Single national (government or otherwise) backbone providers (with or without smaller collaboration/competition)
  - Private regional/national providers, tiers
- Fiscal responsibility
  - Desire to near-optimally utilize installed capacity
  - Install capacity only when fairly sure of business
  - Desire to keep control of their own equipment
  - Desire for uniformity of offerings – “shop window”
- Slow to make new offerings, leverage innovative technology