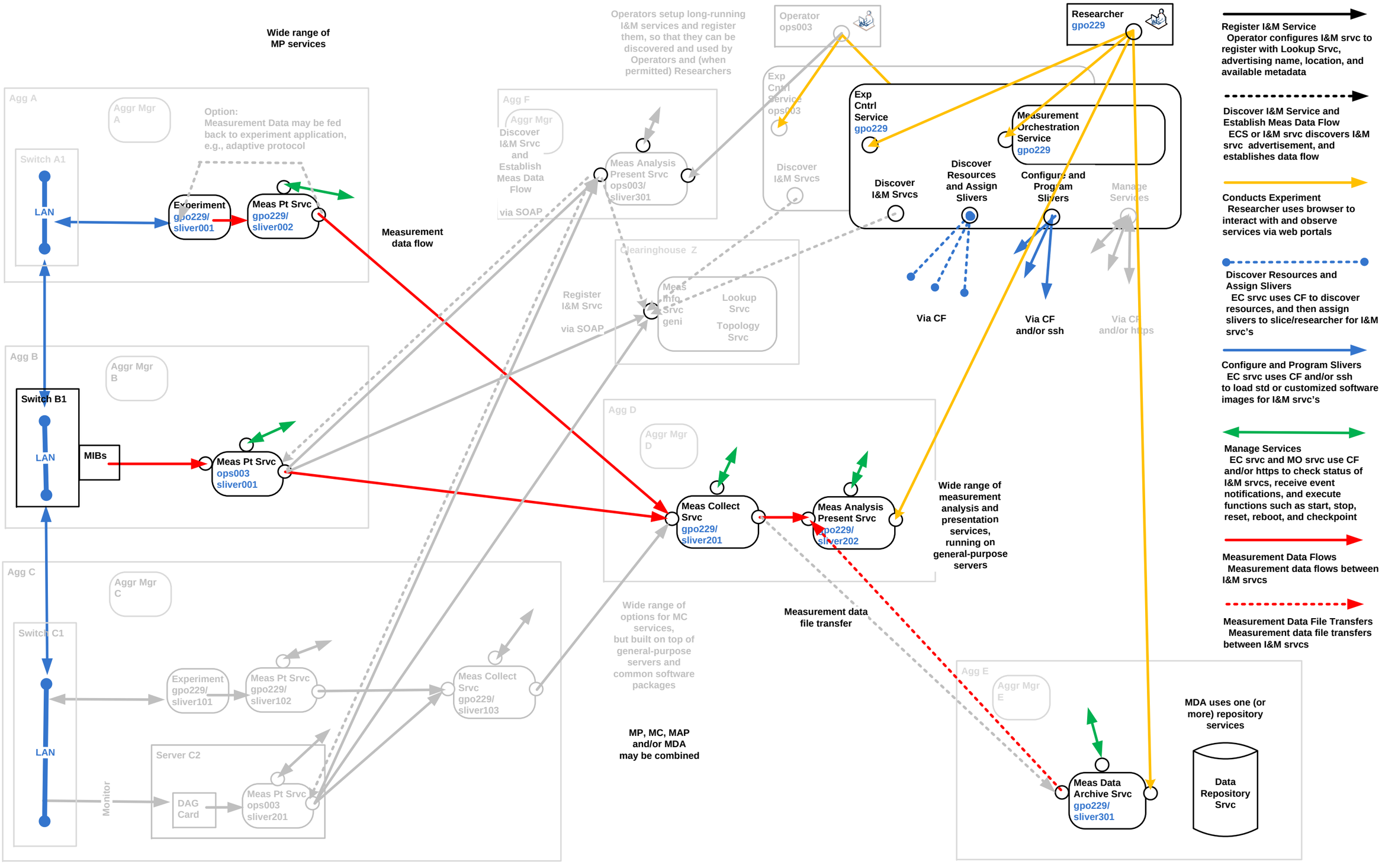
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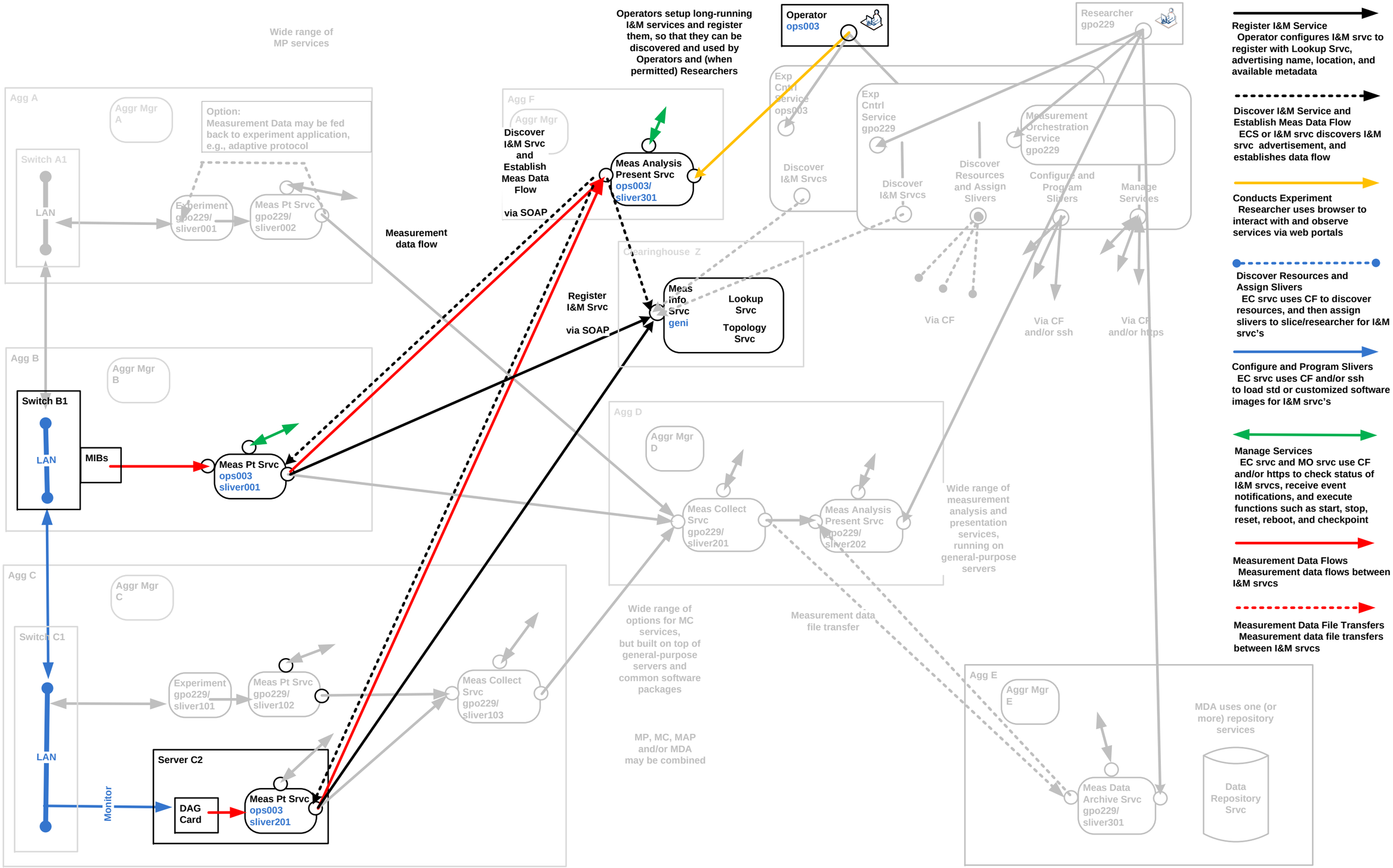
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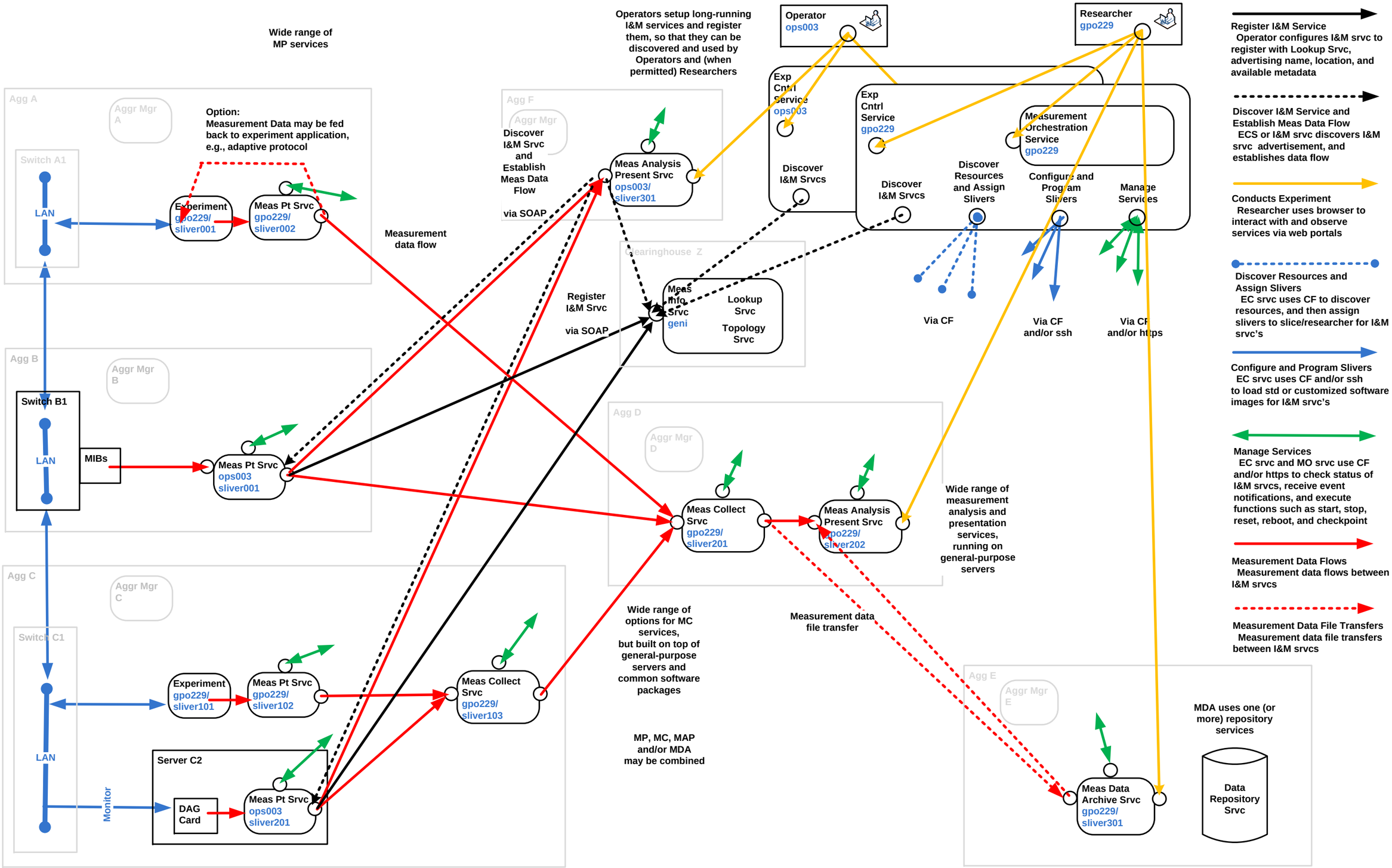
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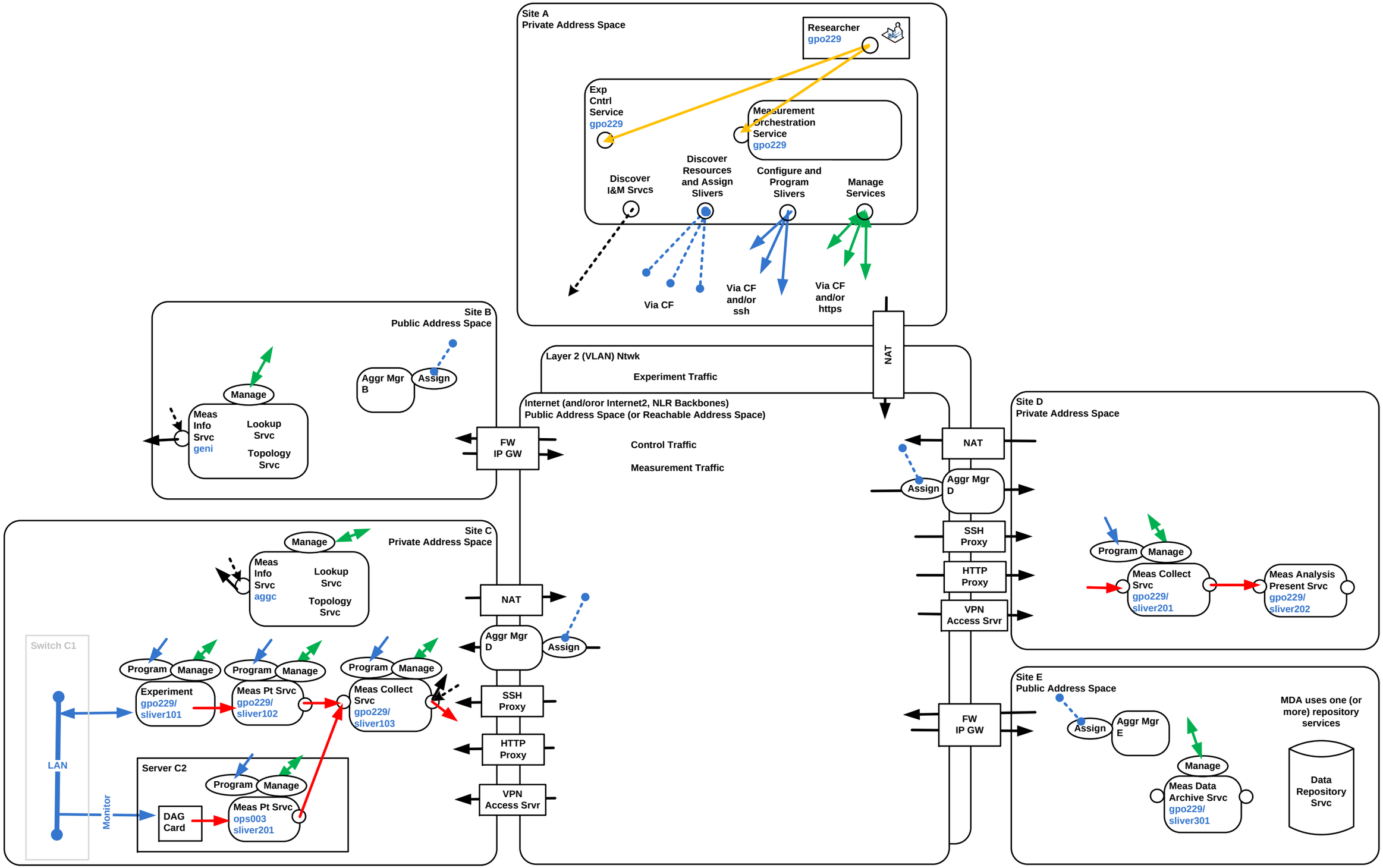
Site A
Private Address Space
Researcher
gpo229
Exp
Cntrl
Service
gpo229
Measurement
Orchestration
Service
gpo229
Discover
I&M Srvcs
Discover
Resources
and Assign
Slivers
Configure and
Program
Slivers
Manage
Services
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and/or
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Via CF
and/or
https
Site B
Public Address Space
Manage
Meas
Info
Srvc
geni
Lookup
Srvc
Topology
Srvc
Aggr Mgr
B
Assign
Layer 2 (VLAN) Ntwk
Experiment Traffic
Internet (and/oror Internet2, NLR Backbones)
Public Address Space (or Reachable Address Space)
Control Traffic
Measurement Traffic
FW
IP GW
NAT
Site D
Private Address Space
NAT
Assign
Aggr Mgr
D
SSH
Proxy
HTTP
Proxy
VPN
Access Srvr
Program
Manage
Meas Collect
Srvc
gpo229/
sliver201
Meas Analysis
Present Srvc
gpo229/
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gpo229/
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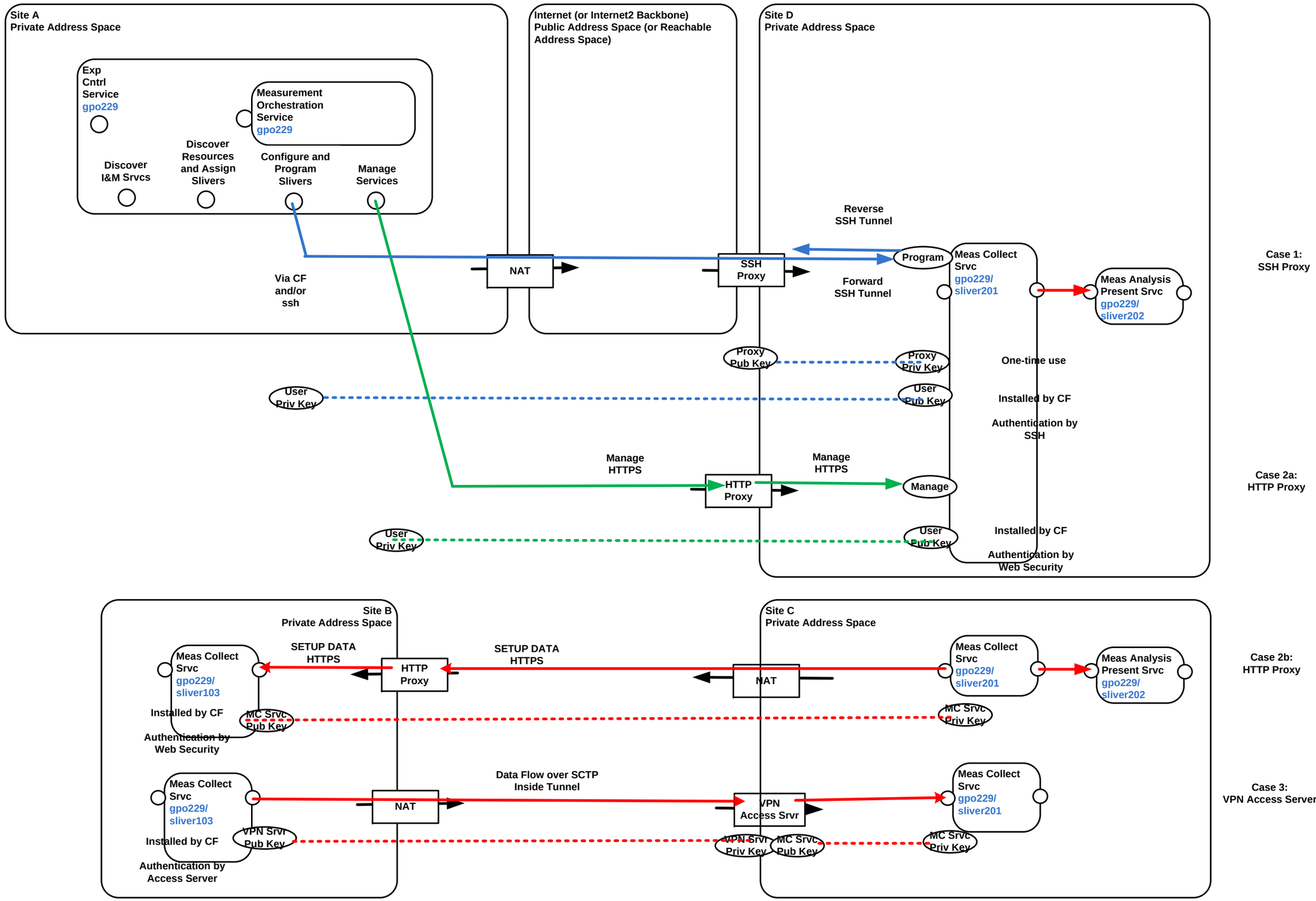
Data
Repository
Srvc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NAT
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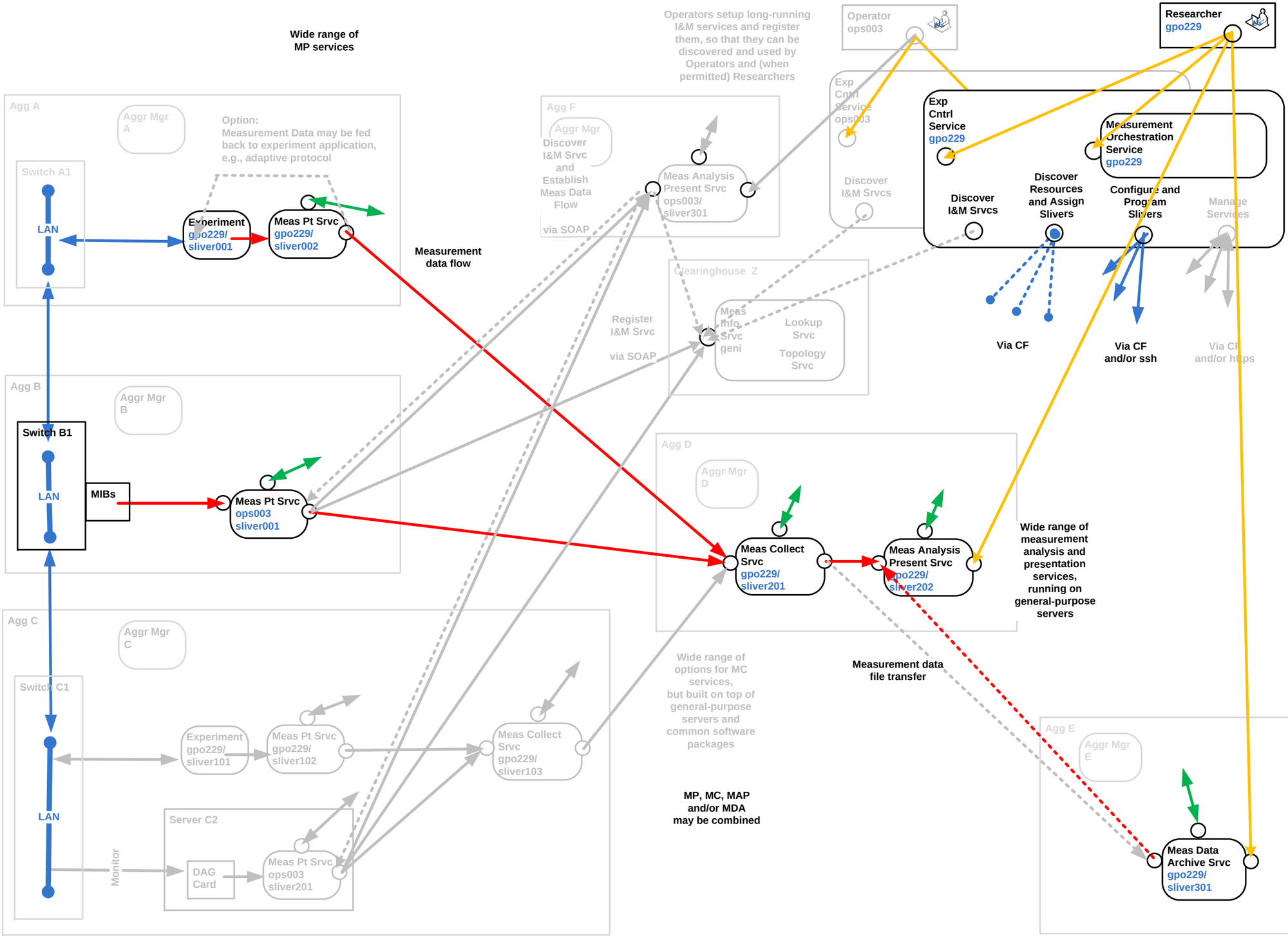
SSH Tunnel
SSH
Proxy
Program
Forward
SSH Tunnel
Meas Collect
Srvc
gpo229/
sliver201
Meas Analysis
Present Srvc
gpo229/
sliver202
Case 1:
SSH Proxy
Proxy
Pub Key
Proxy
Priv Key
One-time use
User
Priv Key
User
Pub Key
Installed by CF
Authentication by
SSH
Manage
HTTPS
Manage
HTTPS
HTTP
Proxy
Manage
Case 2a:
HTTP Proxy
User
Priv Key
User
Pub Key
Installed by CF
Authentication by
Web Security
Site B
Private Address Space
SETUP DATA
HTTPS
HTTP
Proxy
SETUP DATA
HTTPS
NAT
Site C
Private Address Space
Meas Collect
Srvc
gpo229/
sliver201
Meas Analysis
Present Srvc
gpo229/
sliver202
Case 2b:
HTTP Proxy
Meas Collect
Srvc
gpo229/
sliver103
Installed by CF
MC Srvc
Pub Key
MC Srvc
Priv Key
Authentication by
Web Security
Meas Collect
Srvc
gpo229/
sliver103
Data Flow over SCTP
Inside Tunnel
NAT
VPN
Access Srvr
Meas Collect
Srvc
gpo229/
sliver201
Case 3:
VPN Access Server
Installed by CF
VPN Srvr
Pub Key
VPN Srvr
Priv Key
MC Srvc
Pub Key
MC Srvc
Priv Key
Authentication by
Access Server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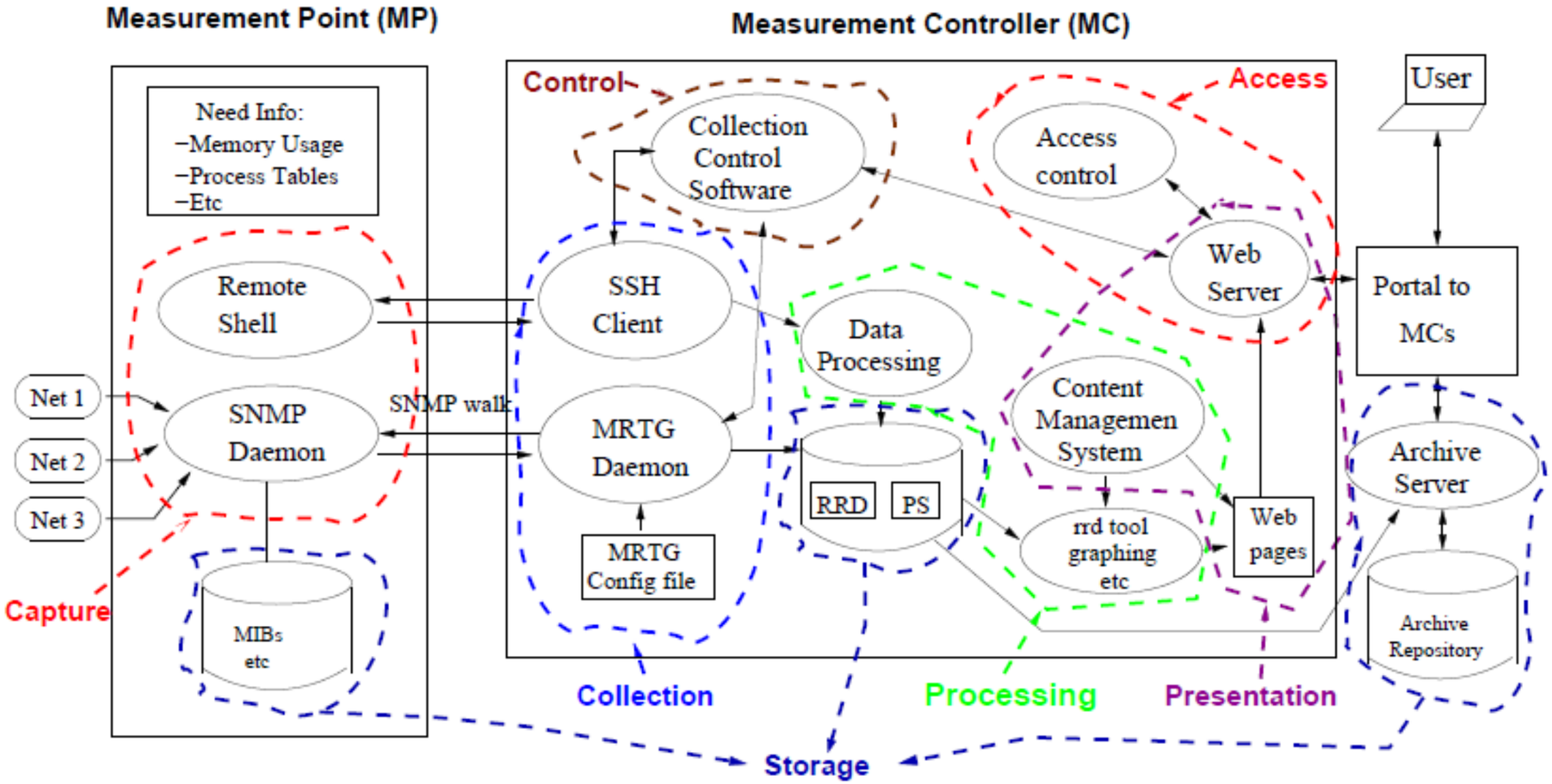
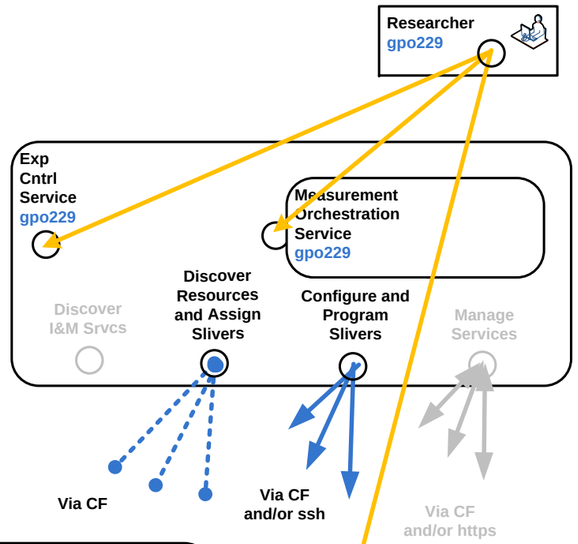


Figure 3: The Architectural Components of the INSTOOLS Toolset

Instrumentation Tools for Researchers (Students)

* Each instance contained in one Aggregate (site)
* Integrated with protoGENI CF
* Meas Orch (MO) srvc:
  * Adds MO srvc to protoGENI Exp Cntrl Srvc that runs in Researcher's browser
  * When Res specifies RSpec for experiment slice, it adds host for *Meas Controller* (MC) sliver
  * Uses info from manifest to identify slivers to be monitored, and dynamically creates config files for SNMP daemon and other capture software
  * Then, it downloads software for *MC* sliver, and it adds MP srvc to each *Experiment Sliver*



Manage Srvcs

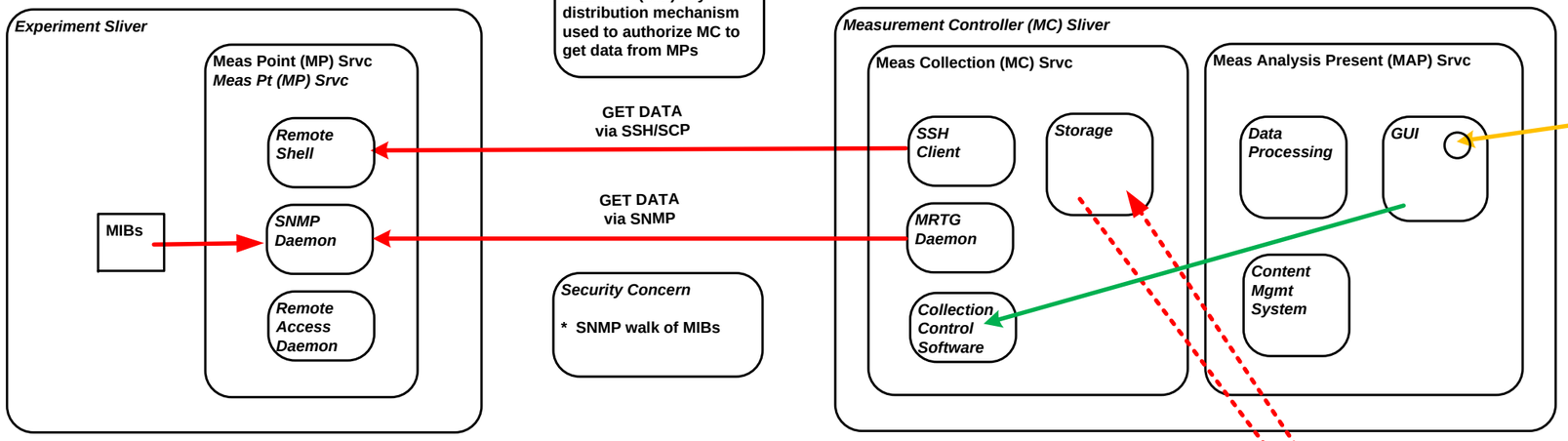
* *MC Srvc* has collection control software
* *MP Srvc* includes remote access daemon to execute capture software
* How?

MP Srvc is automatically loaded into each Experiment Sliver

***MC Sliver* is automatically loaded into each Experiment Slice**

Authorization

* Emulab (ssh) key distribution mechanism used to authorize MC to get data from MPs



Security Concern

* SNMP walk of MIBs

Portal to MCs

* How does this work?

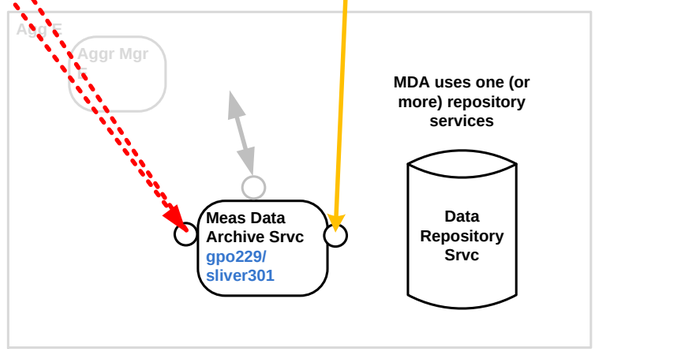
Software	Information	Display Type
SNMPd	Routing Table	Table
	IP Traffic	Graph
	ICMP Traffic	Graph
	TCP Traffic	Graph
	UDP Traffic	Graph
	CPU Utilization	Graph
	Memory Utilization	Graph
	Total Network Traffic	Graph
	Link-specific Traffic	Graph
	Link-specific Unicast Traffic	Graph
ssh/arp	ARP cache	Table
ssh/netstat	TCP streams	Table
ssh/netstat	UDP listeners	Table
ssh/ps	Process list	Table
ssh/lsmod	Installed Kernel Modules	Table

***MP Srvc* includes:**

* SNMP daemon, using existing MIBs, or added MIBs
* tcpdump
* netflow
* custom monitoring code based on pcap library to collect packet stats not captured by SNMP daemon
* ps, vmstat, and SNMP, to capture OS info, such as CPU load, memory load, routing table configs, ARP caches, loaded modules, etc.
* remote access daemon to to execute capture software

Meas Data Schema

* none defined
* metadata not defined



Meas Data Arch Srvc

* srvc not yet defined
* messages not yet defined

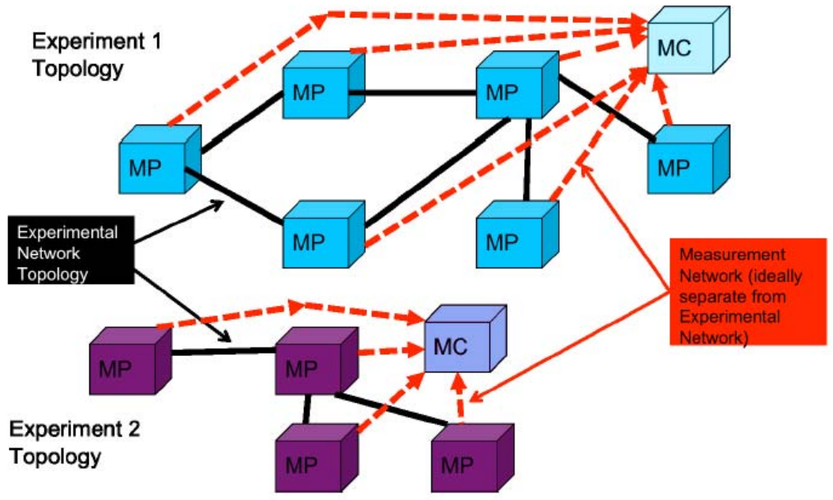


Figure 1: Each experiment/slice has its own MC and instrumentation and measurement network.

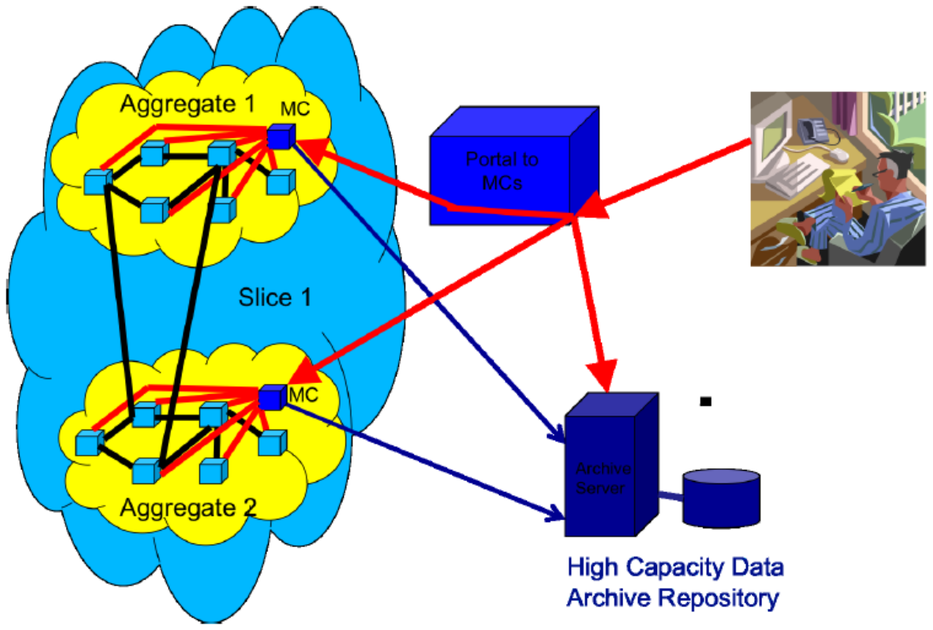
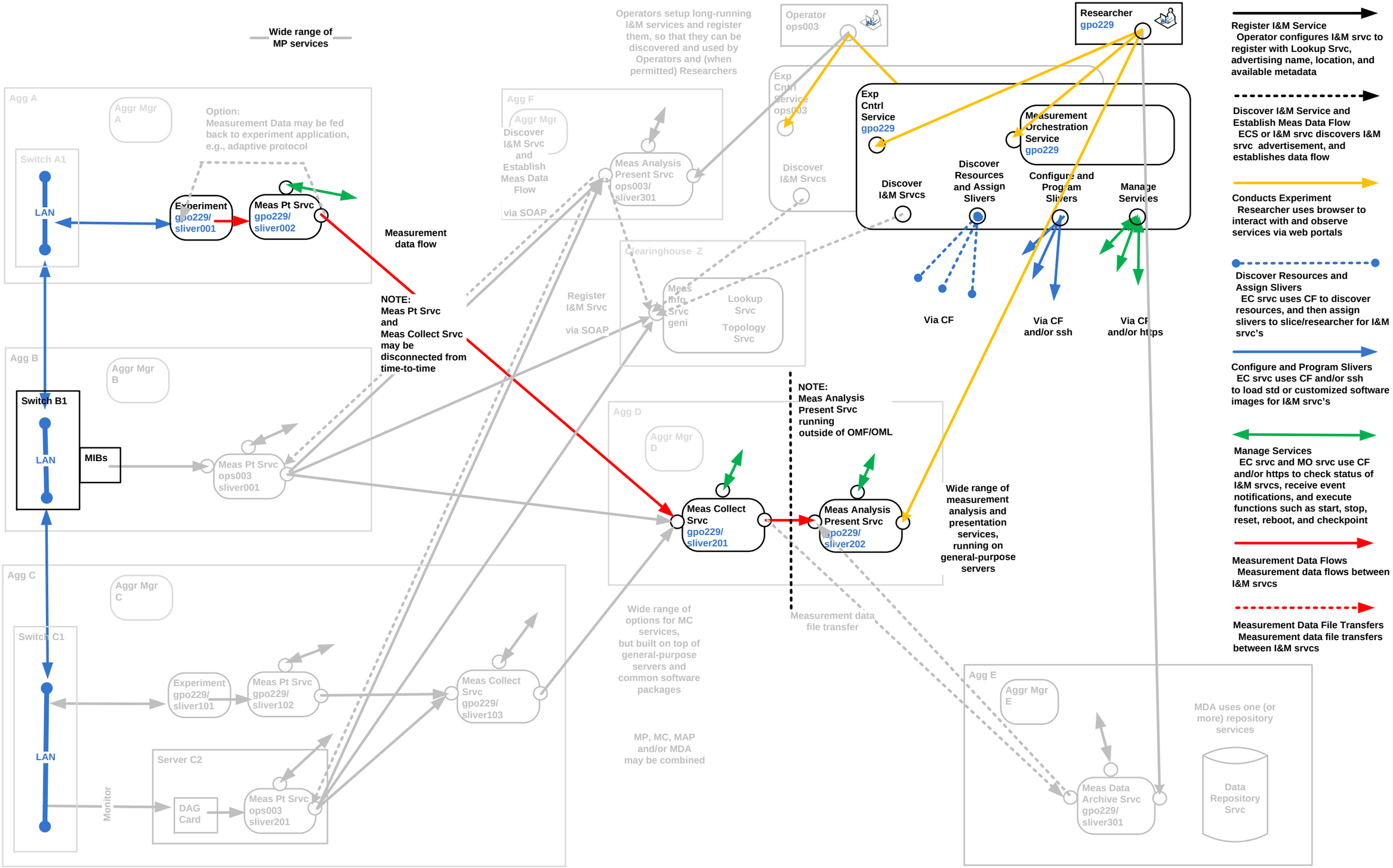


Figure 2: The MC Portal provides users with a single point of entry to their measurement data.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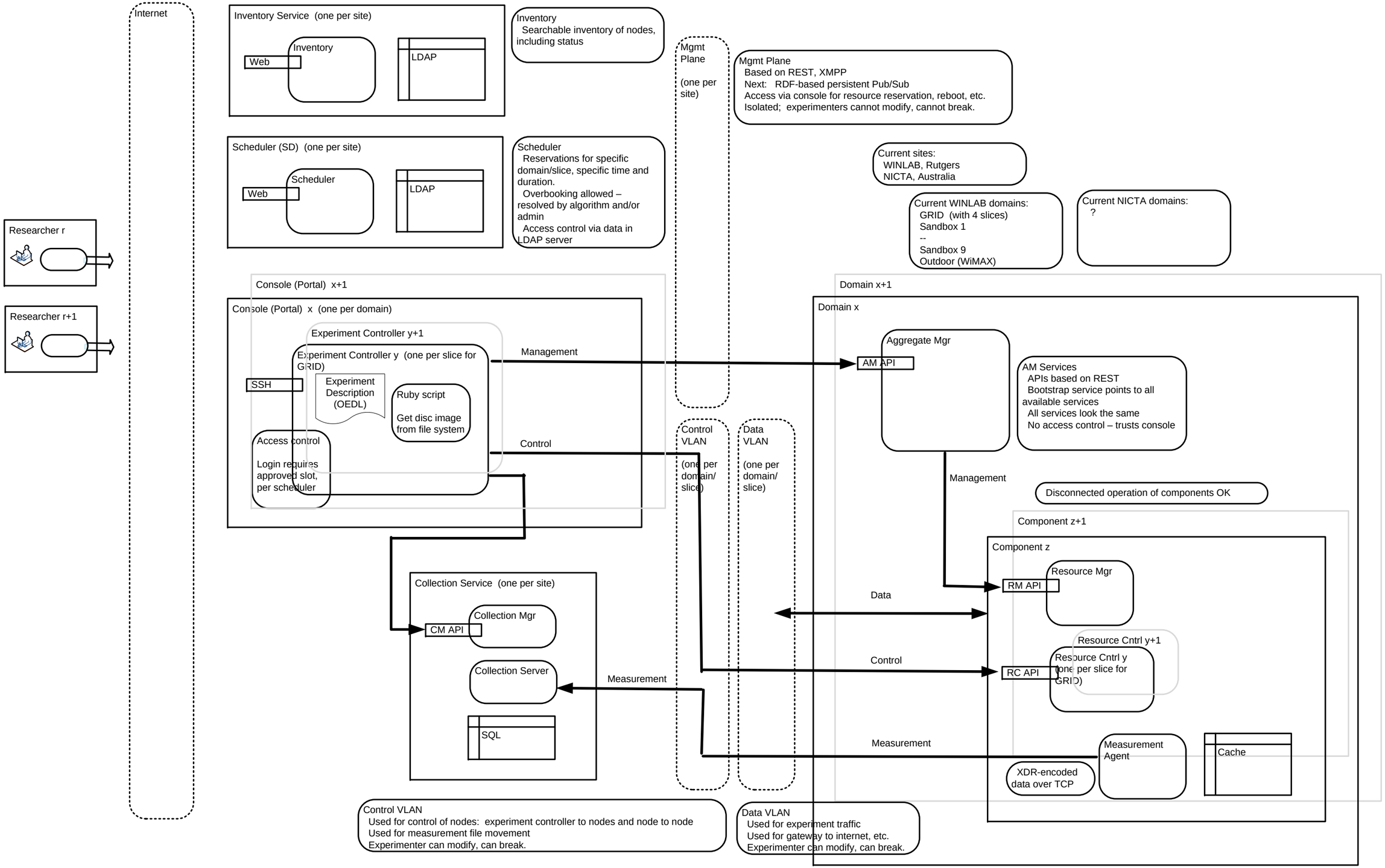

Internet
Researcher r
Researcher r+1
Inventory Service (one per site)
Web
Inventory
LDAP
Inventory
Searchable inventory of nodes, including status
Scheduler (SD) (one per site)
Web
Scheduler
LDAP
Scheduler
Reservations for specific domain/slice, specific time and duration.
Overbooking allowed – resolved by algorithm and/or admin
Access control via data in LDAP server
Mgmt Plane
(one per site)
Mgmt Plane
Based on REST, XMPP
Next: RDF-based persistent Pub/Sub
Access via console for resource reservation, reboot, etc.
Isolated; experimenters cannot modify, cannot break.
Current sites:
WINLAB, Rutgers
NICTA, Australia
Current WINLAB domains:
GRID (with 4 slices)
Sandbox 1
--
Sandbox 9
Outdoor (WiMAX)
Current NICTA domains:
?
Console (Portal) x+1
Console (Portal) x (one per domain)
Experiment Controller y+1
Experiment Controller y (one per slice for GRID)
SSH
Experiment Description (OEDL)
Ruby script
Get disc image from file system
Access control
Login requires approved slot, per scheduler
Management
Control
Control VLAN
(one per domain/ slice)
Data VLAN
(one per domain/ slice)
Domain x+1
Domain x
Aggregate Mgr
AM API
AM Services
APIs based on REST
Bootstrap service points to all available services
All services look the same
No access control – trusts console
Management
Disconnected operation of components OK
Component z+1
Component z
Resource Mgr
RM API
Data
Resource Cntrl y+1
Resource Cntrl y (one per slice for GRID)
RC API
Control
Collection Service (one per site)
Collection Mgr
CM API
Collection Server
SQL
Measurement
Measurement
Measurement Agent
Cache
XDR-encoded data over TCP
Control VLAN
Used for control of nodes: experiment controller to nodes and node to node
Used for measurement file movement
Experimenter can modify, can break.
Data VLAN
Used for experiment traffic
Used for gateway to internet, etc.
Experimenter can modify, can break.

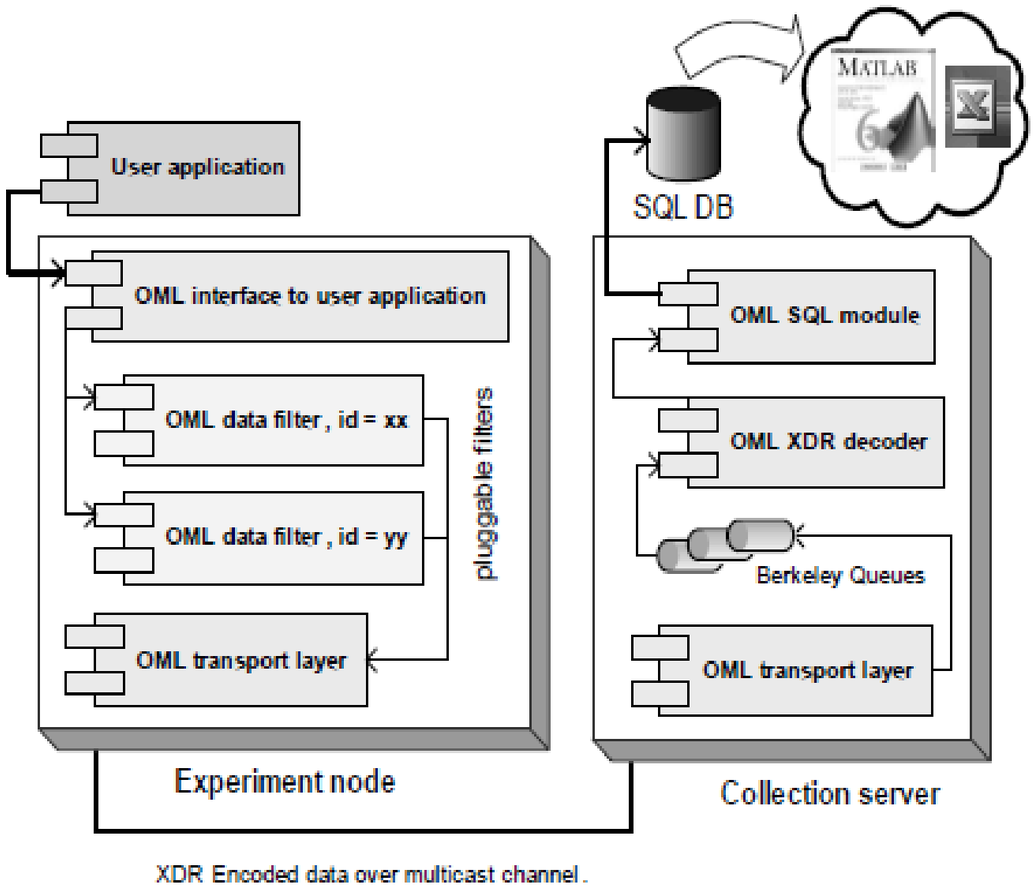


Figure 1. OML component architecture

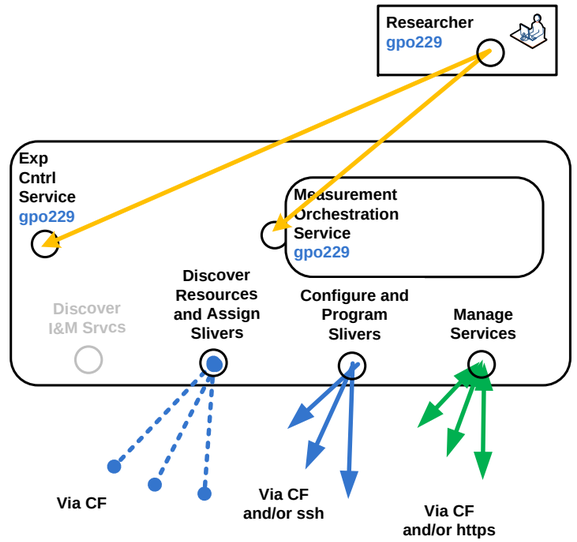
OMF/OML Structure

* One *OML Client* included in each *Experiment Node*

* One *OML Collection Server* provided for each OMF site

* Researcher programs *User Application* and *OML Client* to gather and filter desired measurement data, and define stream to Collection Server

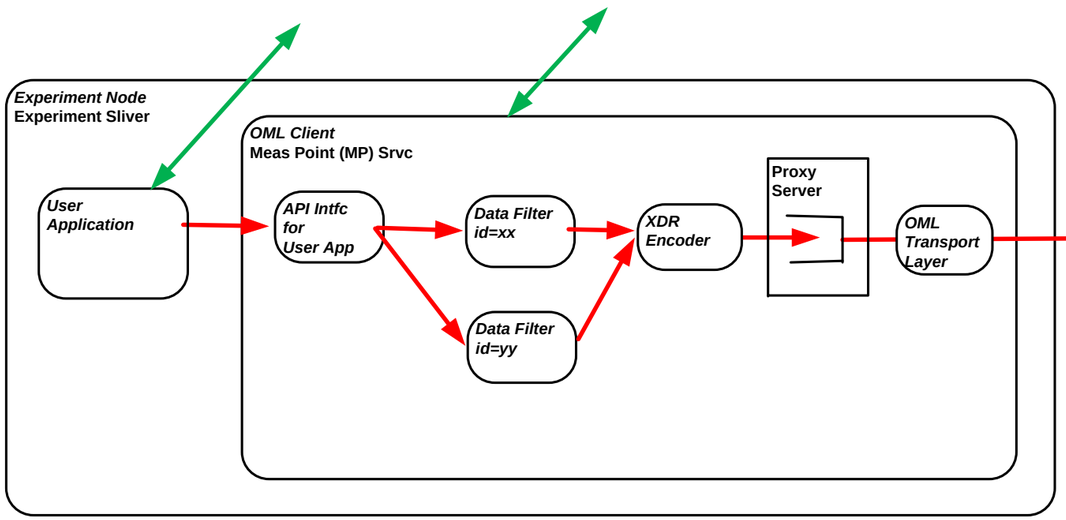
* Meas Data streamed from *OML Client* to *OML Collection Server*

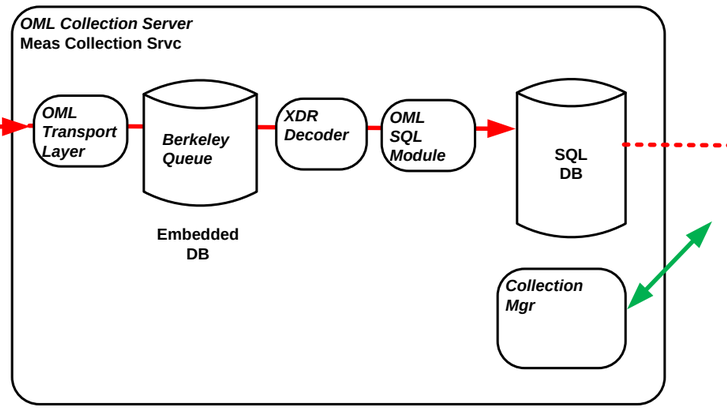


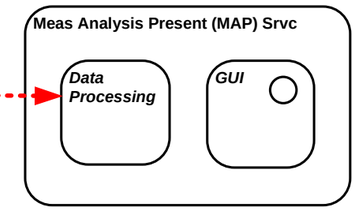
Manage (and Control) Srvcs

* Via HTTP to all srvc's, with APIs based on REST.

* Via HTTP to OML Client srvc, to config files specifying filtering and streaming, which are then compiled into code







Meas Analysis Present Srvc

* Running outside of OMF/OML.

* Can import directly from SQL DB

* EC can arrange to convert tables into graphs

Experiment Portal

* Early prototype

* Each experiment results in a separate page containing all the experiment related information (script, parameter, resources used, time) as well as a pointer to the measurement database.

* Where?

Client API

* Researcher uses web interface to define measurement points and parameters through a web interface, saved as XML config file; causes XSLT-based code generator to generate source code for measurement client.

* Researcher includes measurement-point id's, and metric id's, which dynamically creates a schema.

Meas Data Filters

* Researcher defines filters, separate from User App, so that can easily change data collection behavior

* Can be triggered by various properties, e.g., time, by the no of data values collected, etc.

* Can be triggered by events, e.g., passing a trip line in a mobile application

Meas Data Streams

* Researcher defines measurement streams, gathering data samples and averaging, etc.

* Meas data is series of typed vectors, XDR coded, and then streamed from client to collection server using proprietary OML protocol, on top of TCP, over dedicated Control VLAN
* Considering using IPFIX instead of prop OML protocol; IPFXI typically uses SCTP for transport

* If path becomes disconnected from time-to-time. data is cached in Proxy Server FIFO, and then forwarded when path is reestablished

Meas Data Schema

* Meas data follows schema defined by researcher, including: measurement-point id's, metric id's, etc.

* A sensor (or application, or service) define a set of measurement points, with each measurement point defined by a name and a typed vector (sensor schema).

* At runtime, the experimenter (or operator) provides a streams spec which defines what measurement points are going to be activated and what initial processing is going to be performed - that defines the actual schema going over the wire and/or ending up in the collection database

DB Schema

* Application definition is used to create DB schema for experiment, using XSLT.

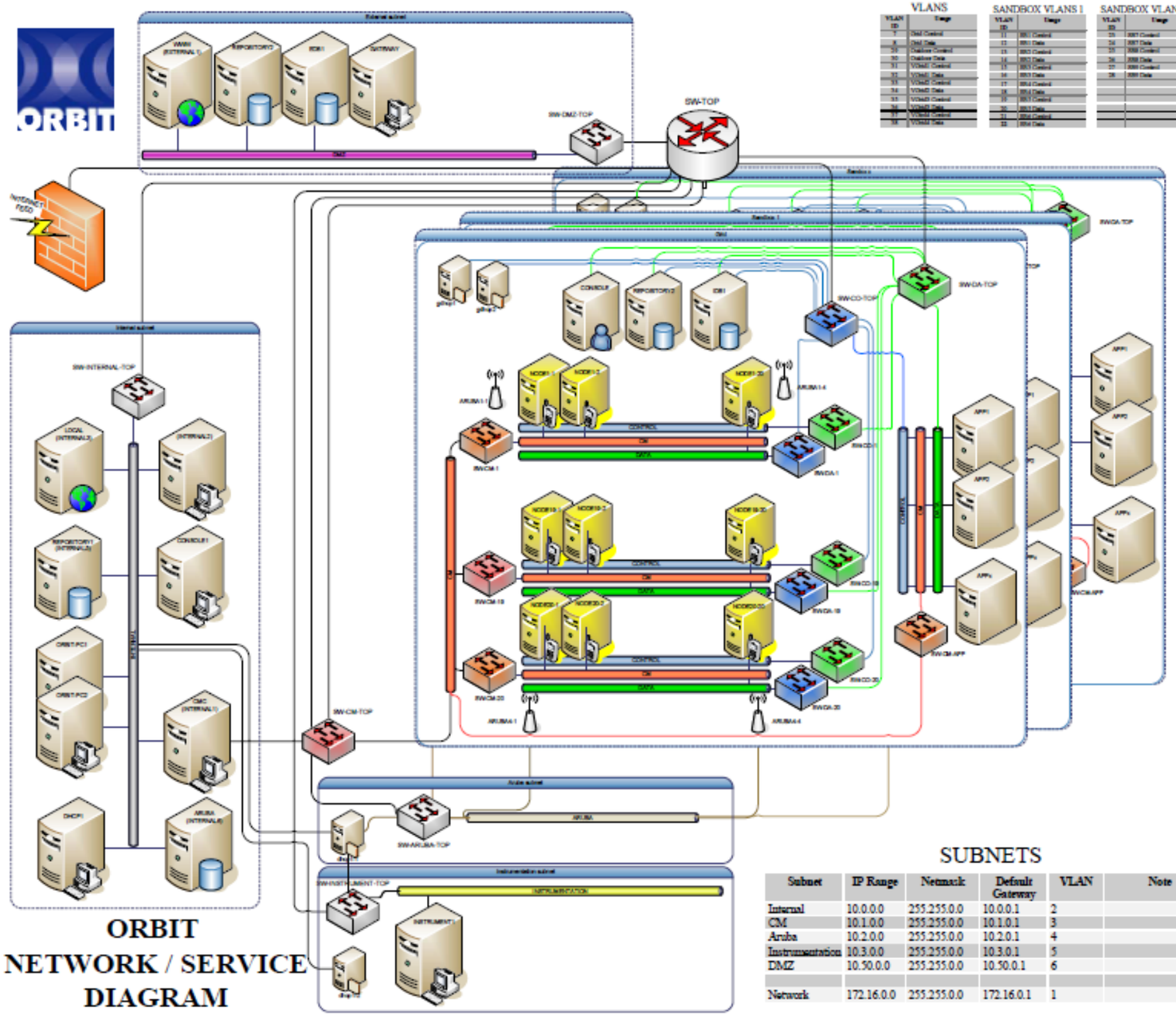
* DB table is created for each measurement point, names based on id attribute of the group element.

* Includes mandatory fields for name/ id, timestamp, sequence number

* Protocol is self describing

* Server automatically creates a table for every distinct stream (distinct in terms of schema not source).

* Streams carry their own name which is translated into a database using a simple naming convention.



VLANS

VLAN ID	Usage
1	Mgt Control
2	Mgt Data
10	Outdoor Control
50	Outdoor Data
51	VChnl1 Control
52	VChnl1 Data
53	VChnl2 Control
54	VChnl2 Data
55	VChnl3 Control
56	VChnl3 Data
57	VChnl4 Control
58	VChnl4 Data

SANDBOX VLANS 1

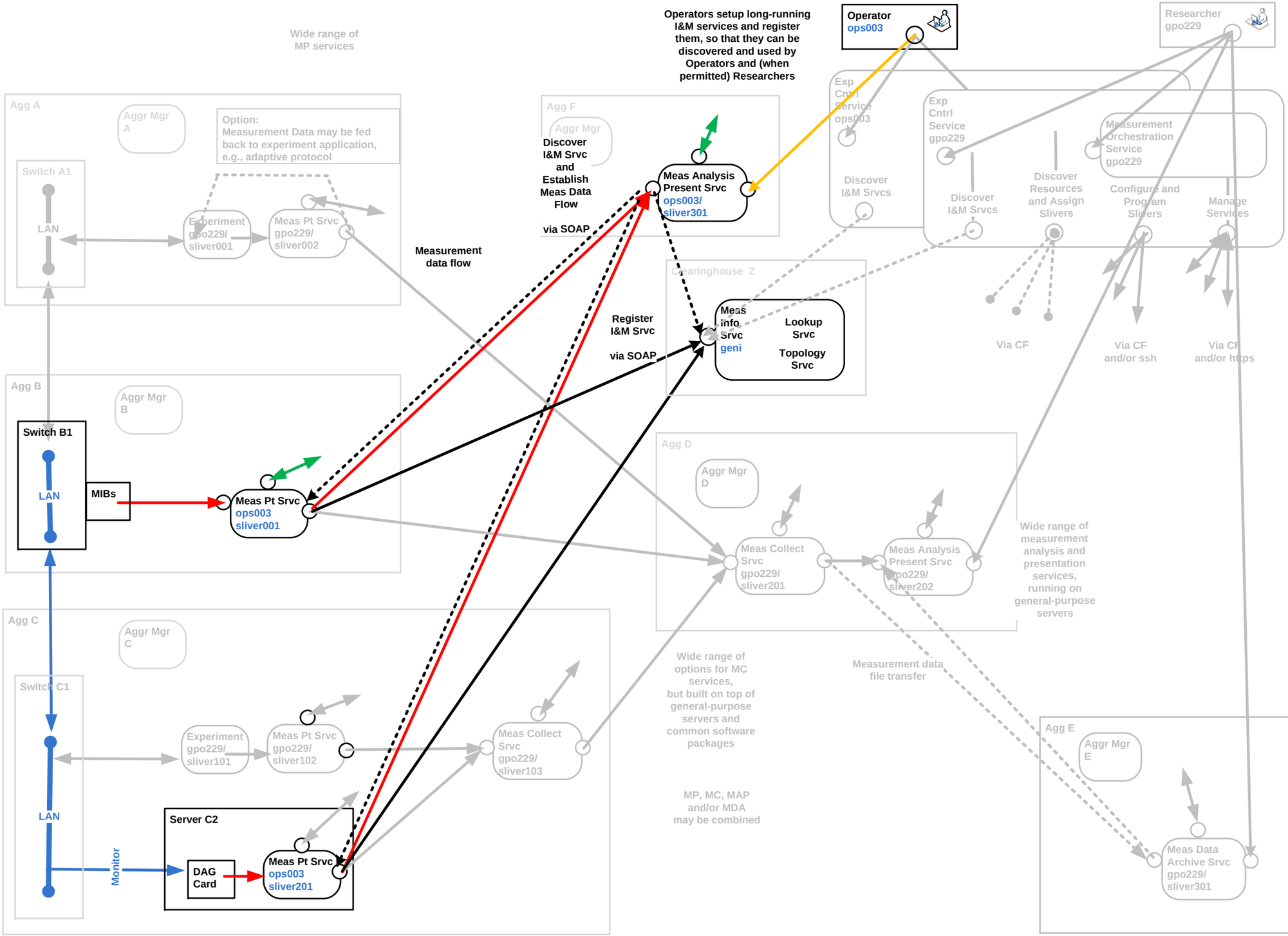
VLAN ID	Usage
11	SB1 Control
12	SB1 Data
13	SB2 Control
14	SB2 Data
15	SB3 Control
16	SB3 Data
17	SB4 Control
18	SB4 Data
19	SB5 Control
20	SB5 Data
21	SB6 Control
22	SB6 Data

SANDBOX VLANS 2

VLAN ID	Usage
23	SB7 Control
24	SB7 Data
25	SB8 Control
26	SB8 Data

SUBNETS

Subnet	IP Range	Netmask	Default Gateway	VLAN	Note
Internal	10.0.0.0	255.255.0.0	10.0.0.1	2	
CM	10.1.0.0	255.255.0.0	10.1.0.1	3	
Aruba	10.2.0.0	255.255.0.0	10.2.0.1	4	
Instrumentation	10.3.0.0	255.255.0.0	10.3.0.1	5	
DMZ	10.50.0.0	255.255.0.0	10.50.0.1	6	
Network	172.16.0.0	255.255.0.0	172.16.0.1	1	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Aggr Mgr A
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Meas Pt Srvc gpo229/ sliver002
Agg F
Aggr Mgr
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Exp Cntrl Service gpo229
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Discover I&M Srvcs
Discover Resources and Assign Slivers
Configure and Program Slivers
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Clearinghouse Z
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Topology Srvc
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Via CF
Via CF and/or ssh
Via CF and/or https
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Aggr Mgr B
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LAN
MIBs
Meas Pt Srvc ops003 sliver001
Agg D
Aggr Mgr D
Meas Collect Srvc gpo229/ sliver201
Meas Analysis Present Srvc gpo229/ sliver202
Wide range of measurement analysis and presentation services, running on general-purpose servers
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Aggr Mgr C
Switch C1
Experiment gpo229/ sliver101
Meas Pt Srvc gpo229/ sliver102
Meas Collect Srvc gpo229/ sliver103
Wide range of options for MC services, but built on top of general-purpose servers and common software packages
Measurement data file transfer
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Server C2
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MP, MC, MAP and/or MDA may be combined
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Data Repository Srvc
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Measurement Data File Transfers
Measurement data file transfers between I&M srvcs

perfSONAR – PS
services written in perl
follow SOA web services approach
run on Linux

Meas Info (MI) Srvc

Two (or more) gLSs.

Receive REGISTERs only from hLSs

Contain for each hLS: name, location, metadata summary of available srvcs

Update each other

Global Lookup Srvc (gLS)

UPDATE

Global Lookup Srvc (gLS)

Topology Srvc (TS)

QUERY, ADD, UPDATE, REPLACE

TS Query Request
TS Add Request
TS Update Request
TS Replace Request

One hLS for each entity/domain/aggregate

Receives REGISTERs from MA Srvcs, including: name, location, metadata of available srvcs

Takes registered info and compiles metadata summary of available srvcs

Each hLS registers with one (or more) gLSs, providing name, location, metadata summary of available srvcs

Home Lookup Srvc (hLS)

REGISTER
LS Register Request
LS Deregister Request
LS Keepalive Request

QUERY (first)
LS Query Request - XQuery
LS Query Request – Discovery
LS Key Request

Operators setup long-running I&M services and register them, so that they can be discovered and used by Operators and (when permitted) Researchers

Each MA srvc registers with a hLS, providing name, location, metadata of available srvcs

REGISTER
LS Register Request
LS Deregister Request
LS Keepalive Request

QUERY (second)
LS Query Request - XQuery
LS Query Request – Discovery
LS Key Request

Manage Services GUI

* perfAdmin (CGI script to locate and manage perfSONAR services and data)

* How does this work?

Switch B1
LAN
MIBs

Meas Point (MP) Srvc

Meas Pt (MP) Srvc

Meas Archive (MA) Srvc

Meas Analysis Present (MAP) Srvc

Client

GUI

Operator
ops003

REQUEST (third), SETUP DATA

Echo Request
Metadata Key Request
Setup Data Request

MP Srvc types

* command line
* status via SNMP (e.g., interface counter)
* status via TL1 (e.g., optical devices)
* telnet/SSH
* perfSONAR-BUOY, OWAMP (one-way latency)
* perfSONAT-BUOY, BWCTL (bandwidth testing)
* PingER, Ping scheduled testing (round trip latency)

MA Srvc types

* RRD database
* SQL database

All perfSONAR Messages
addressed to each service at a service URL
formatted in XML using SOAP over HTTP
always a Request and then a Response
(currently) no encryption
(currently) no authentication and authorization
(since Authentitcation Srvc (AS) not yet built or deployed)

Each message follows perfSONAR schema, and contains;
message container
one or more one metadata elements
zero or more data elements

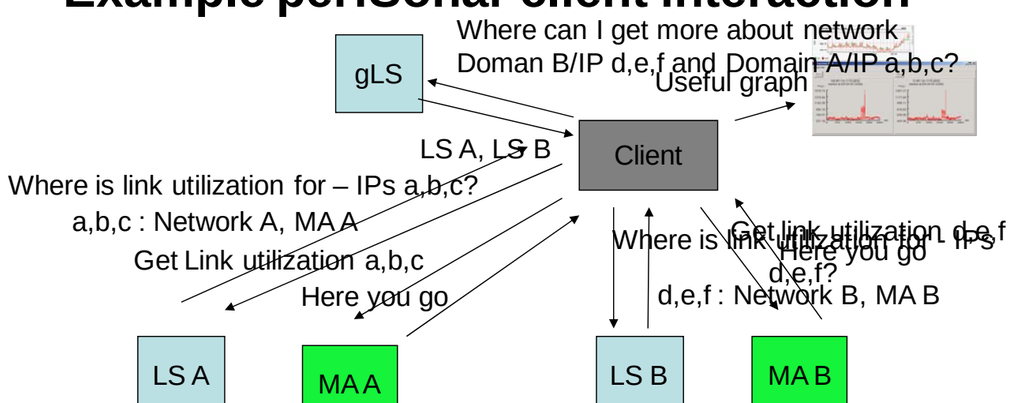
Client types

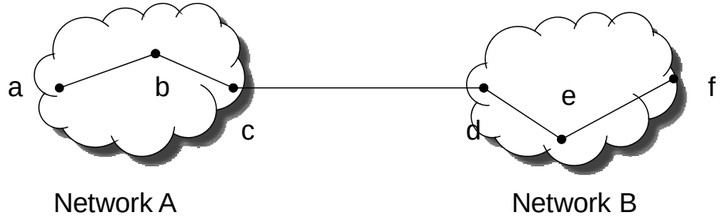
* match *MP Srvc*s
* command line
* status via SNMP and TL1
* telnet/SSH
* perfSONAR-BUOY, OWAMP and BWCTL
* PingER

GUI types

* active Service
* GMAPS
* acad (Java-based visualization)
* E2EMon (link monitoring)
* ESNet (domain utilization)
* trace (traceroute visualization)
* perfAdmin (CGI script to locate and manage perfSONAR services and data)
* perfER GUI (displys the results of pingER testing)
* perfSONAR-BUOY (displays the results of latency and bandwidth testing)

Example perfSonar client interaction





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Scalable Framework for Representation and Exchange of Network Measurements

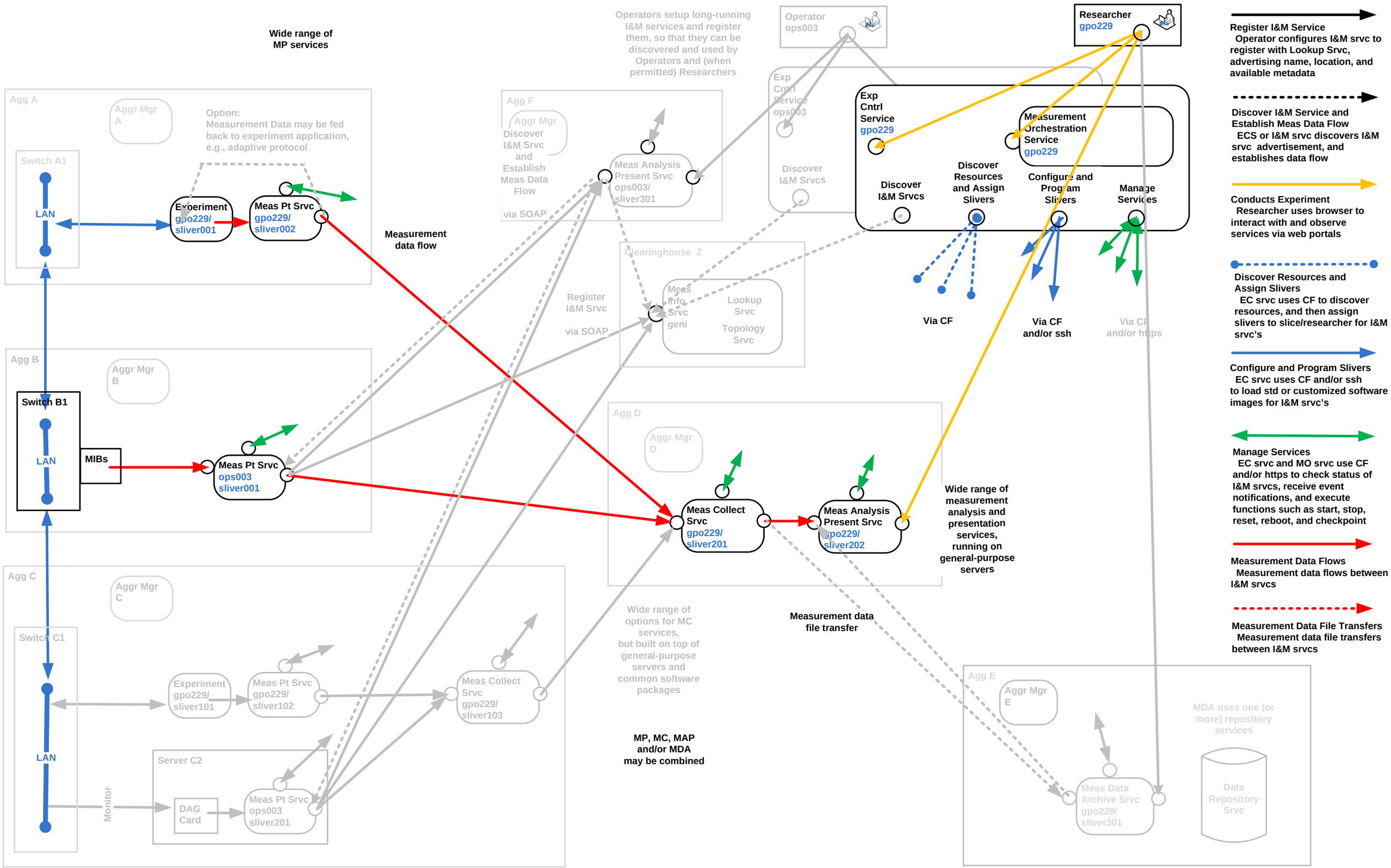
Jason Zurawski, Martin Swany
Department of Computer and Information Sciences
University of Delaware, Newark, DE 19716
{*zurawski, swany*}*@cis.udel.edu*

Dan Gunter
Lawrence Berkeley National Laboratory
Berkeley, CA 94720
dkgunter@lbl.gov

Figure 1. NM-WG Base Schema

The metadata section is subdivided into three parts, only the first of which is required:

- Subject – The physical or logical entity being described. For example, a host pair or router address. Like the subject of the sentence: *Host A to Host B* measured ICMP latency is 100ms.
- EventType – The canonical name of the aspect of the subject being measured, or the actual event (i.e. "characteristic") being sought. Like the object of the sentence: Host A to Host B *measured ICMP latency* is 100ms.
- Parameters – The way in which the description is being gathered or performed. For example, command-line arguments to *traceroute* or whether the round-trip delay packet used ICMP or UDP. Like the descriptive clause of the sentence: *When you use* 100 *byte packets,* Host A to Host B ICMP latency is 100ms.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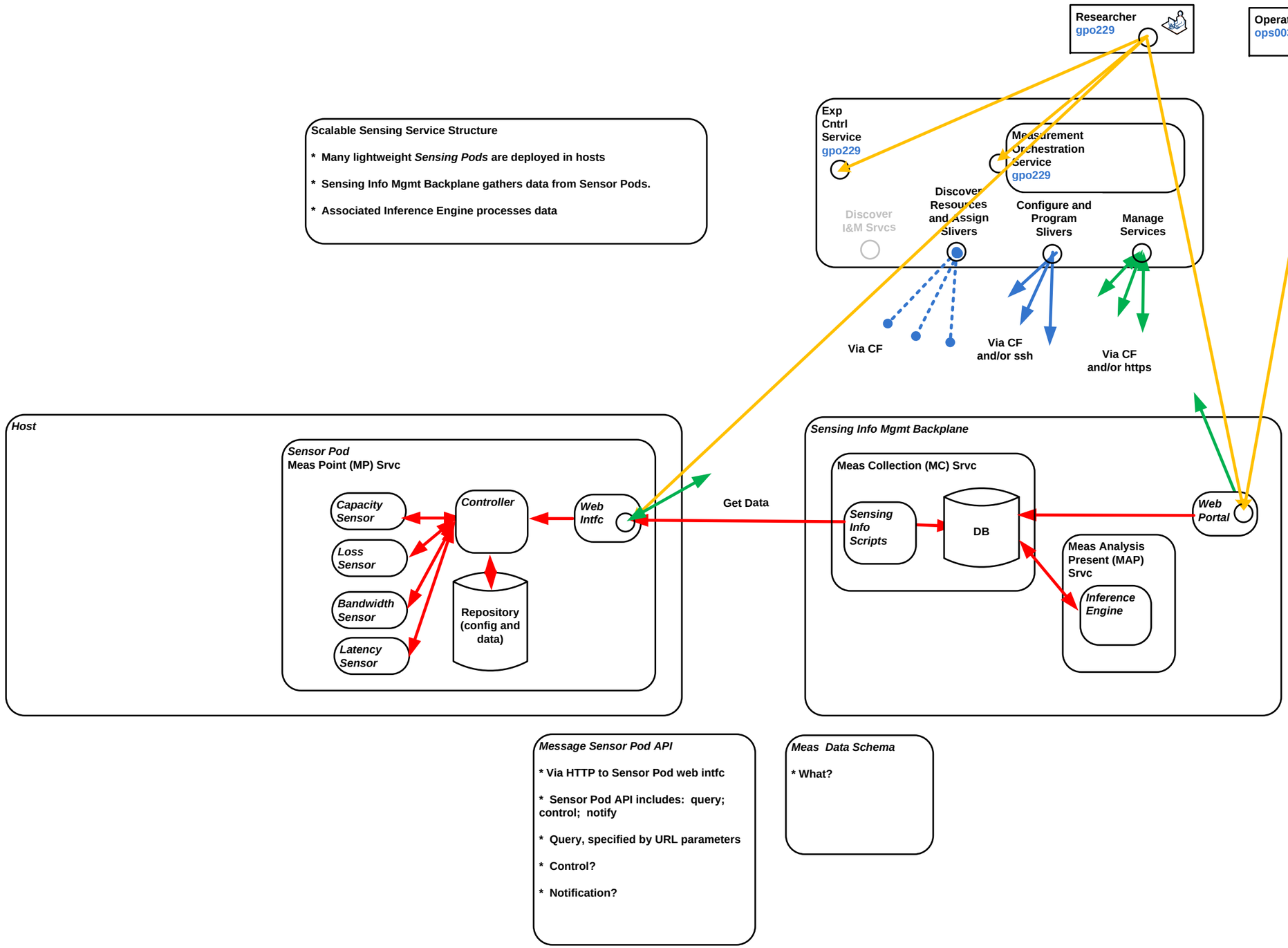
Scalable Sensing Service Structure

* **Many lightweight *Sensing Pods* are deployed in hosts**
* **Sensing Info Mgmt Backplane gathers data from Sensor Pods.**
* **Associated Inference Engine processes data**

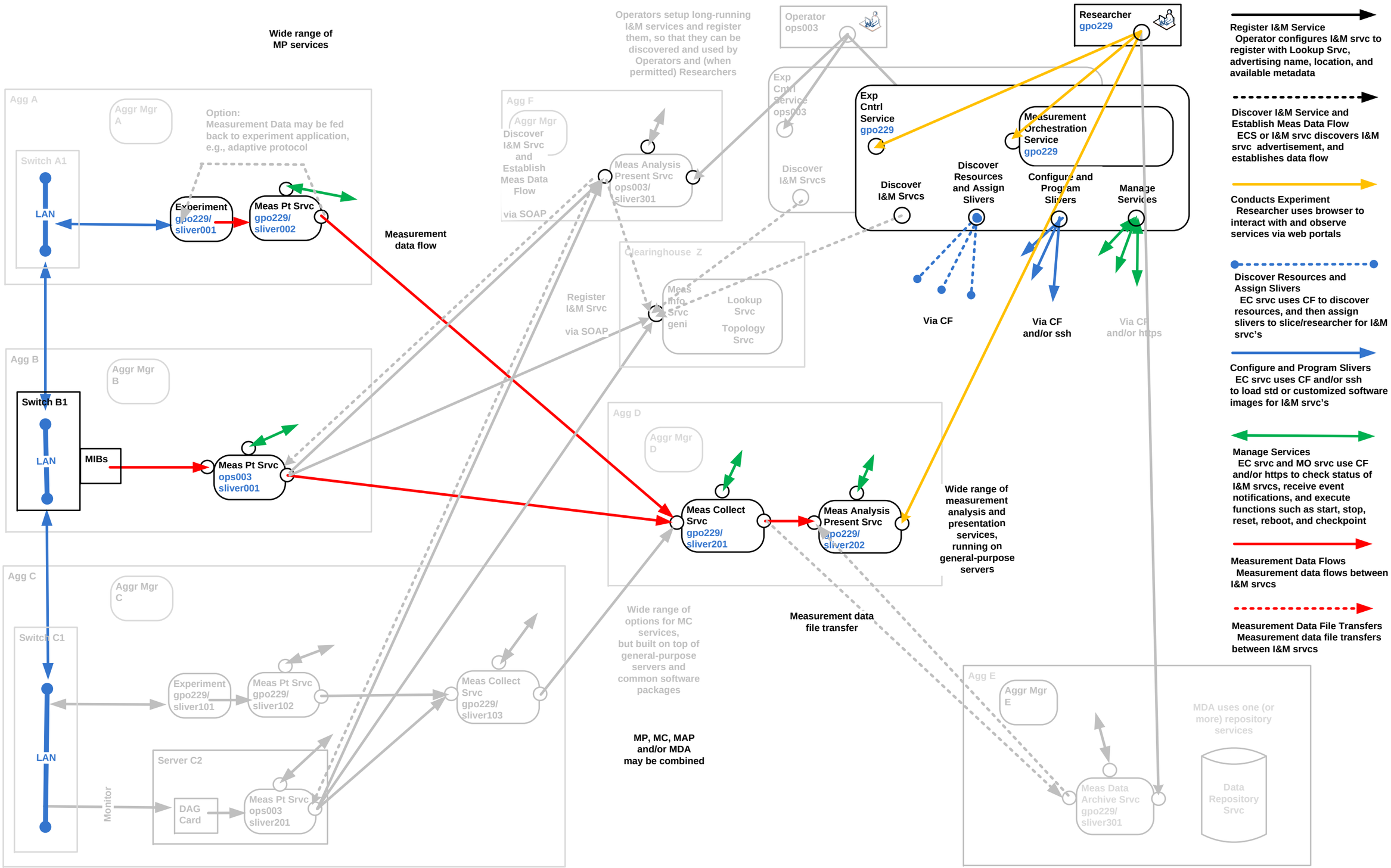


Message Sensor Pod API

* **Via HTTP to Sensor Pod web intfc**
* **Sensor Pod API includes: query; control; notify**
* **Query, specified by URL parameters**
* **Control?**
* **Notification?**

Meas Data Schema

* **What?**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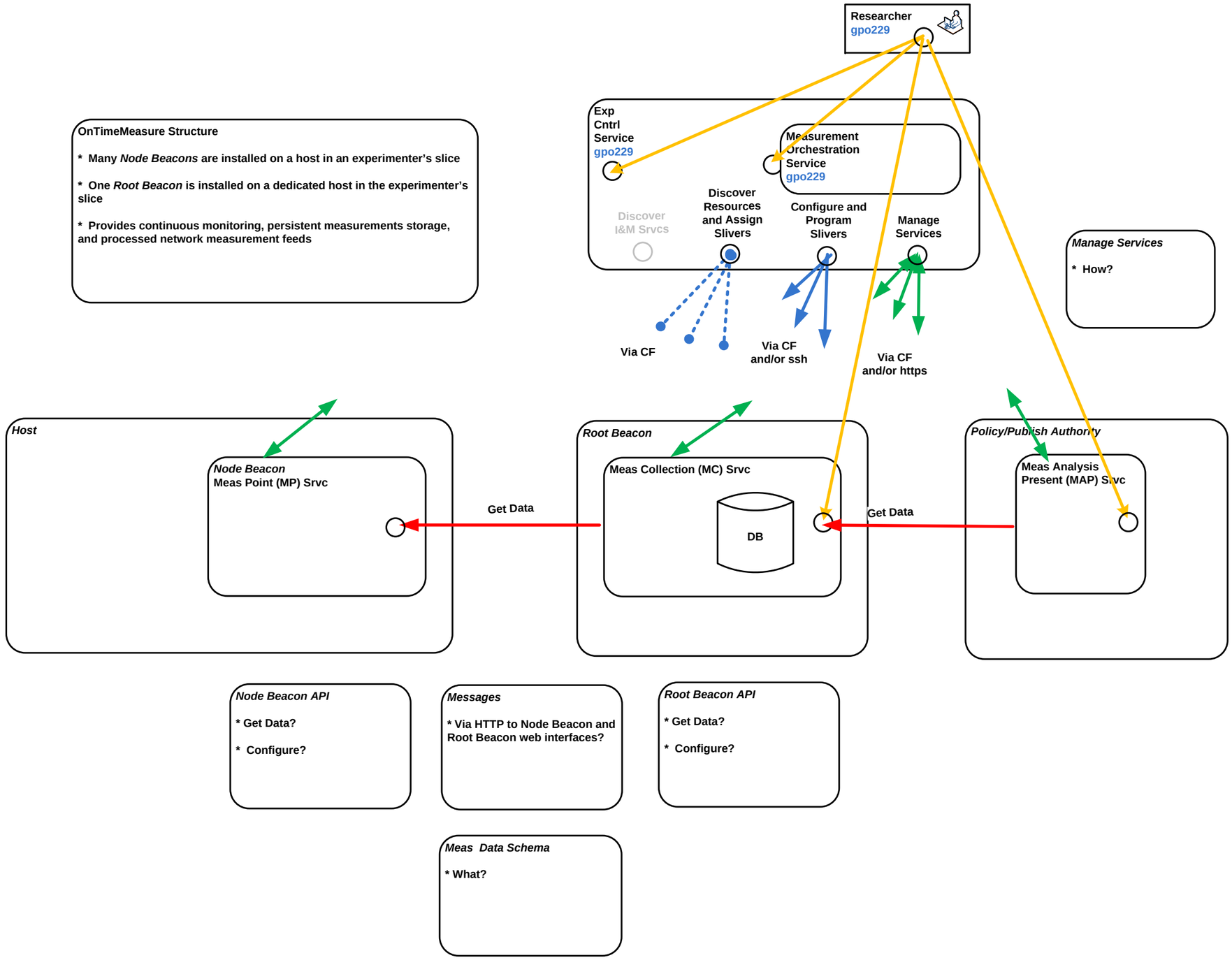
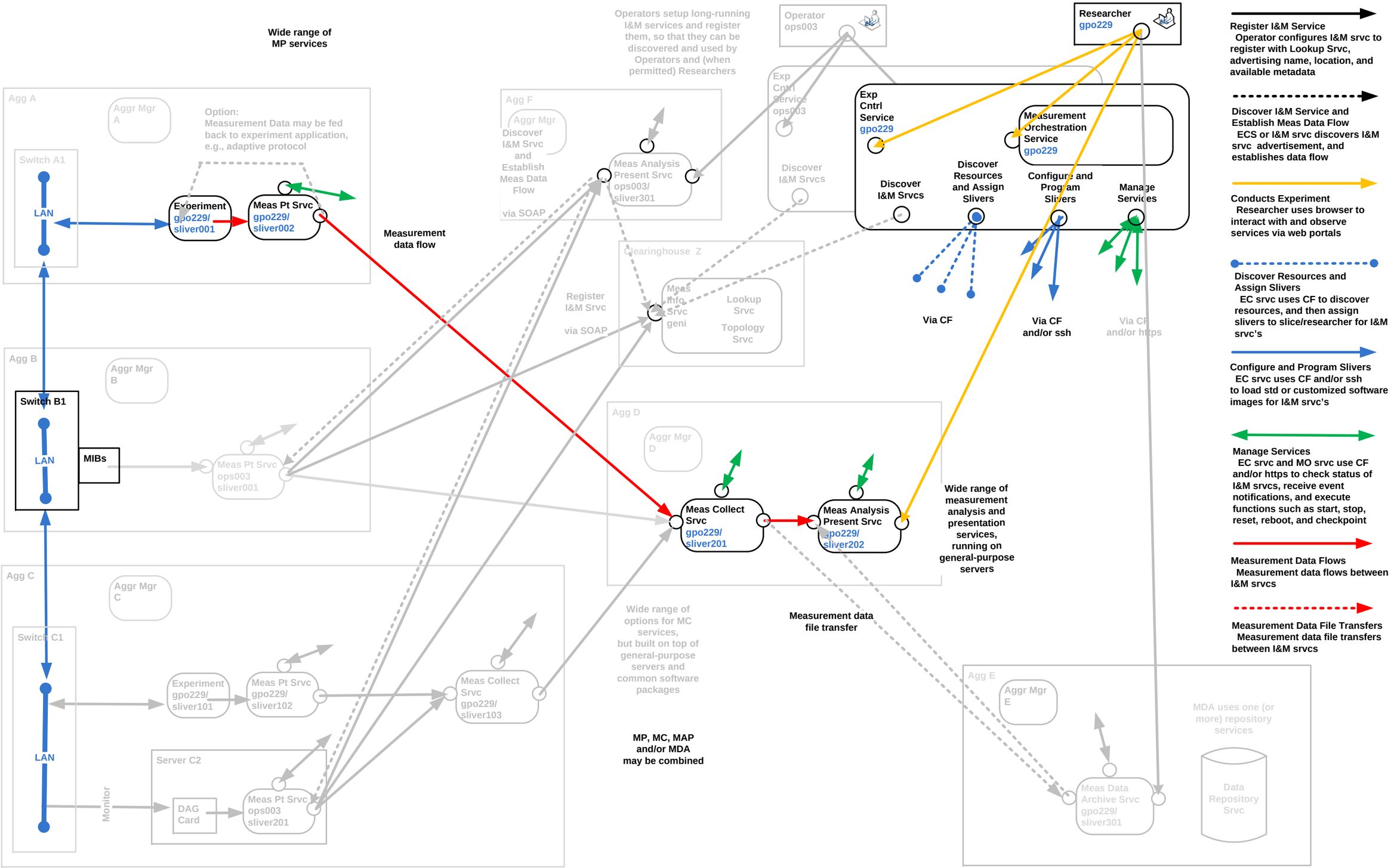

OnTimeMeasure Structure
* Many Node Beacons are installed on a host in an experimenter's slice
* One Root Beacon is installed on a dedicated host in the experimenter's slice
* Provides continuous monitoring, persistent measurements storage, and processed network measurement feeds
Researcher
gpo229
Exp Cntrl Service
gpo229
Measurement Orchestration Service
gpo229
Discover I&M Srvcs
Discover Resources and Assign Slivers
Configure and Program Slivers
Manage Services
Via CF
Via CF and/or ssh
Via CF and/or https
Manage Services
* How?
Host
Node Beacon
Meas Point (MP) Srvc
Get Data
Root Beacon
Meas Collection (MC) Srvc
DB
Get Data
Policy/Publish Authority
Meas Analysis Present (MAP) Srvc
Node Beacon API
* Get Data?
* Configure?
Messages
* Via HTTP to Node Beacon and Root Beacon web interfaces?
Root Beacon API
* Get Data?
* Configure?
Meas Data Schema
* What?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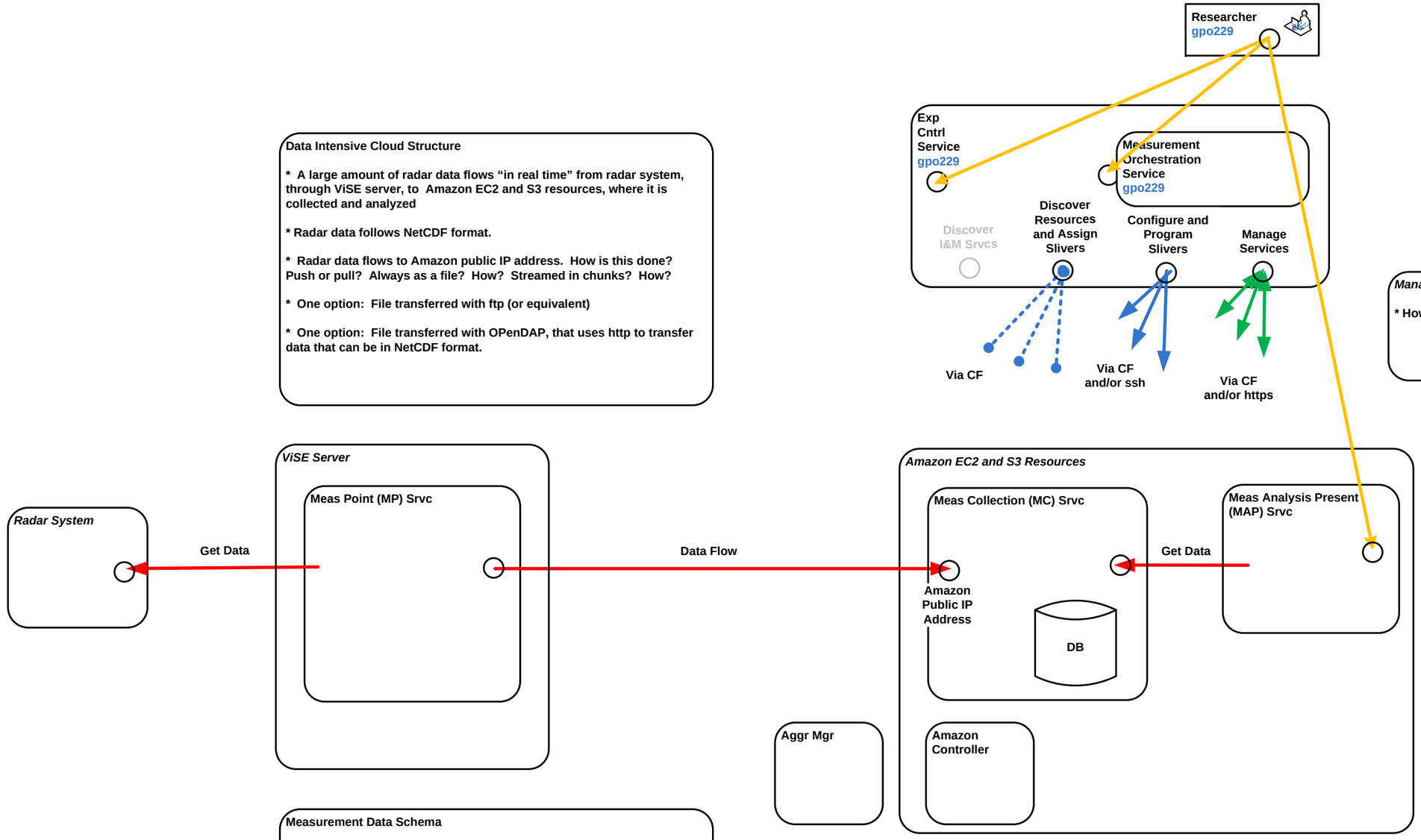
Aggr Mgr E
MDA uses one (or more) repository services
Meas Data Archive Srvc gpo229/ sliver301
Data Repository Srvc
Register I&M Service
Operator configures I&M srvc to register with Lookup Srvc, advertising name, location, and available metadata
Discover I&M Service and Establish Meas Data Flow
ECS or I&M srvc discovers I&M srvc advertisement, and establishes data flow
Conducts Experiment
Researcher uses browser to interact with and observe services via web portals
Discover Resources and Assign Slivers
EC srvc uses CF to discover resources, and then assign slivers to slice/researcher for I&M srvc's
Configure and Program Slivers
EC srvc uses CF and/or ssh to load std or customized software images for I&M srvc's
Manage Services
EC srvc and MO srvc use CF and/or https to check status of I&M srvcs, receive event notifications, and execute functions such as start, stop, reset, reboot, and checkpoint
Measurement Data Flows
Measurement data flows between I&M srvcs
Measurement Data File Transfers
Measurement data file transfers between I&M srvcs


Researcher
gpo229
Exp Cntrl Service
gpo229
Measurement Orchestration Service
gpo229
Discover I&M Srvcs
Discover Resources and Assign Slivers
Configure and Program Slivers
Manage Services
Via CF
Via CF and/or ssh
Via CF and/or https
Manage Srvcs
* How?
Data Intensive Cloud Structure
* A large amount of radar data flows “in real time” from radar system, through ViSE server, to Amazon EC2 and S3 resources, where it is collected and analyzed
* Radar data follows NetCDF format.
* Radar data flows to Amazon public IP address. How is this done? Push or pull? Always as a file? How? Streamed in chunks? How?
* One option: File transferred with ftp (or equivalent)
* One option: File transferred with OPenDAP, that uses http to transfer data that can be in NetCDF format.
ViSE Server
Meas Point (MP) Srvc
Radar System
Get Data
Data Flow
Amazon EC2 and S3 Resources
Meas Collection (MC) Srvc
Get Data
Meas Analysis Present (MAP) Srvc
Amazon Public IP Address
DB
Aggr Mgr
Amazon Controller
Measurement Data Schema
* Radar data follows NetCDF format.
* NetCDF is: “self-describing, machine independent, binary, data format, that supports the creation, access and sharing of array-oriented scientific data.”
* “Self-describing” means that there is a header that describes the rest of the filke, in particular the data arrays, as well as arbirtrary file metadata in the form of name/value attributes.
* Various users of NetCDF (such as Climate and Forecast (CF) have guidelines for metadata.

DOR (Digital Object Registry)

* Provides Meas Data Arch Srvc (and additional archive services)

* Allows Operator/Researcher to archive Meas Data Files, and retrieve them

* From another I&M srvc, MDA srvc can provide these basic functions: put/update file; get file; delete file

* Interfaces to the MDA srvc include: https; also ftp?; also sftp?

* When file is first introduced, it is assumed that file contains type info (extension), metadata, and "file self description" info. A wide range of files and associated metadata is permitted by the MDA srvc.

* When file is first introduced, MDA srvc assigns a unique identifier, which is a handle, that is attached to the file, and can be used to retrieve the file

* When file is first introduced, or at any later time, the MDA srvc provides a convenient service to allow Operator/Researcher to add identification metadata so that files are stored in an organized fashion, and can be found by searches/queries.

* MDA srvc allows Operator/Researcher to view organized files, and find them by searches/queries. Multiple views are supported.

* Each file is "owned" by a GENI slice and one or more users (operators/researchers)

* The MDA srvc allows the owner to specify who has read and/or write access to the file.

* The MDA srvc utilizes the mechanisms provided by the CF to authenticate and authorize users.

MDA Srvc protocol and API

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Assume: API as specified by CNRI for ADL (Advanced Distributed Learining) srvc (CNRI)

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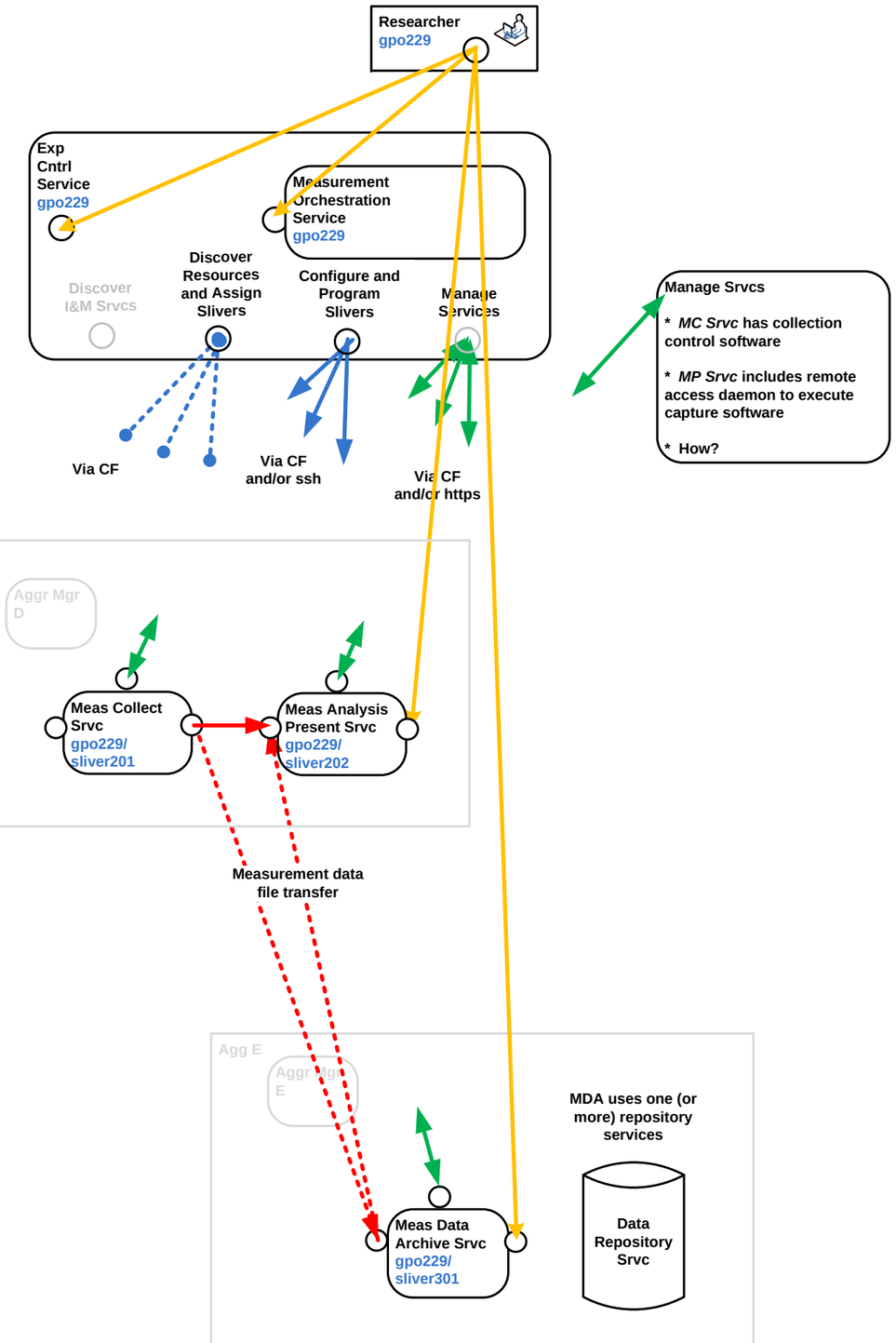
Assume: CF drops public keys of authorized users into MDA srvc, so that: presence of key indicates an "account" on the MDA srvc; additional info indicates nature of access (CNRI)



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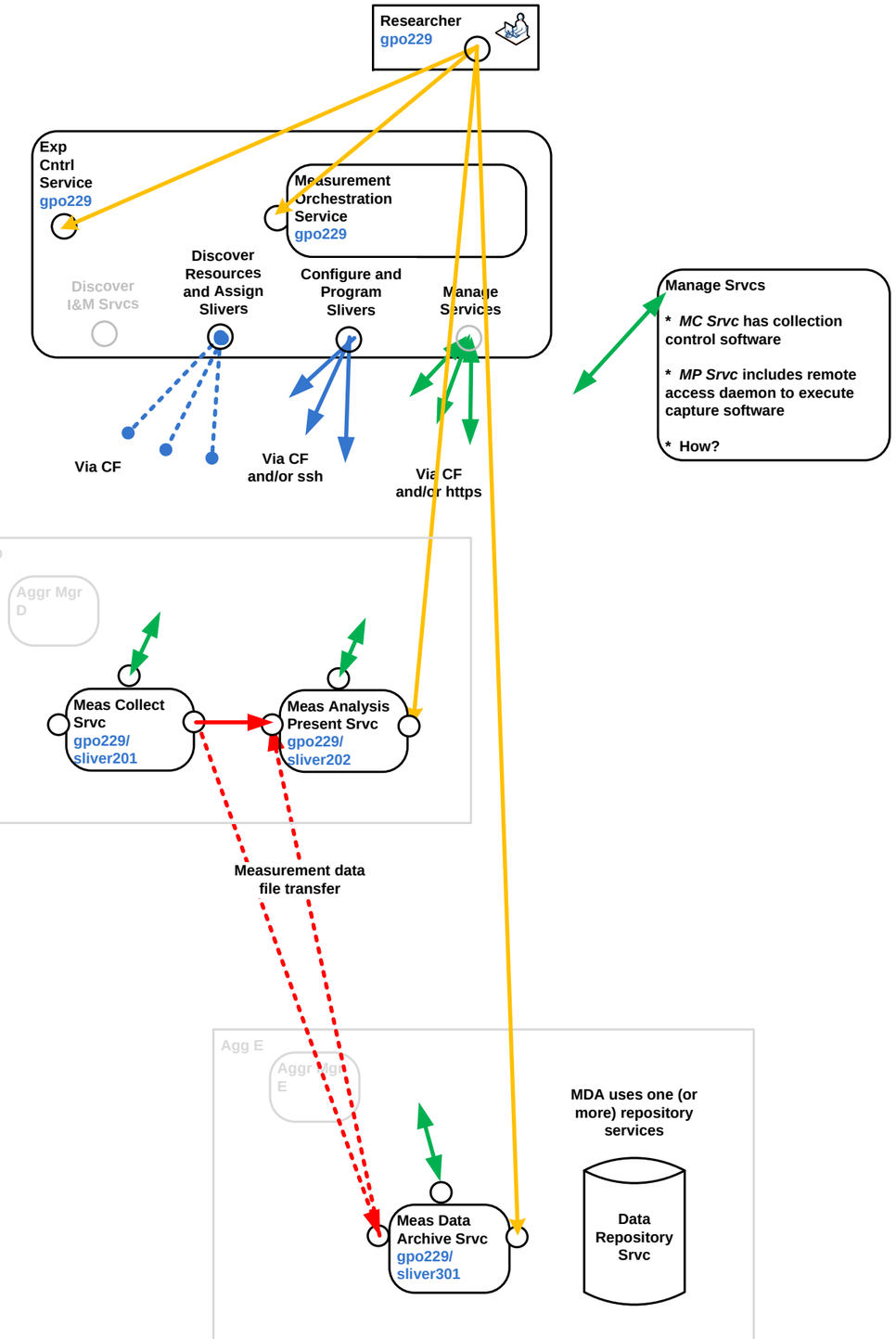


MDA Srvc file organization, views and queries

*** When file is first introduced, or at any later time, the MDA srvc provides a convenient service to allow Operator/Researcher to add identification metadata so that files are stored in an organized fashion, and can be found by searches/queries.**

*** MDA srvc allows Operator/Researcher to view organized files, and find them by searches/queries. Multiple views are supported.**

Assume: Basic view follows current Emulab tree-like file structure, from ops.emulab.net server (Evan)

```
/proj                    <--- This folder contains all the sub-folders for each project
.../proj_A
.../proj_B
  .
  .
  .
.../PNI                  <--- a real project name
...../deltas
...../exp                <--- This folder contains all the sub-folders for each experiment
...../exp_A
...../exp_B
       .
       .
       .
...../test1              <--- a real experiment name
...../archive
...../bin
...../datastore
...../logs
...../swapinfo
...../tbdata              <--- important folder contains all kinds of experiment data and logs
.....activity.log
.....assign.log
.....environment
.....eventkey
.....linktest
.....ltmap
.....ltmap.gz
.....ltpmap
.....ltpmap.gz
.....nsfile.ns
.....startexp.log
.....swapexp.log
.....test1.ns
.....test1.png
.....topomap
.....topomap.gz
.....webkey
...../tftpboot
...../tmp
...../groups
...../images
...../logs
...../rpms
...../tarfiles
...../templates
...../tiplogs


/groups                   <--- Each project has a default group with the same name of the project. And each project also has other groups of users(with different
privileges) associated with it
.../PNI -> /proj/PNI

/usr/testbed               <--- This folder contains the testbed software

/users                   <--- This folder contains user accounts just like regular /home folder in Linux system
.../chyz198                <--- This is my account registered in Utah Emulab, all my personal keys are here

/share                   <--- This folder used to keep the data intend to be shared by all users
```

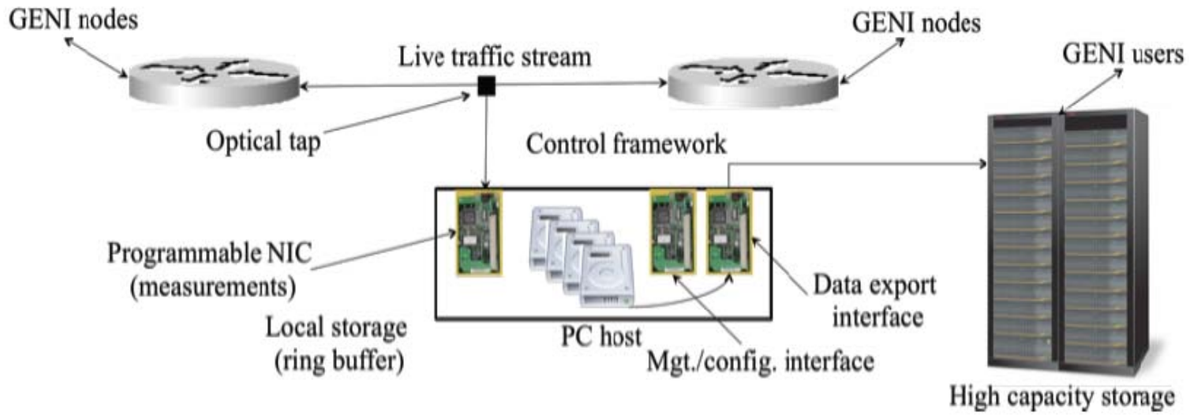
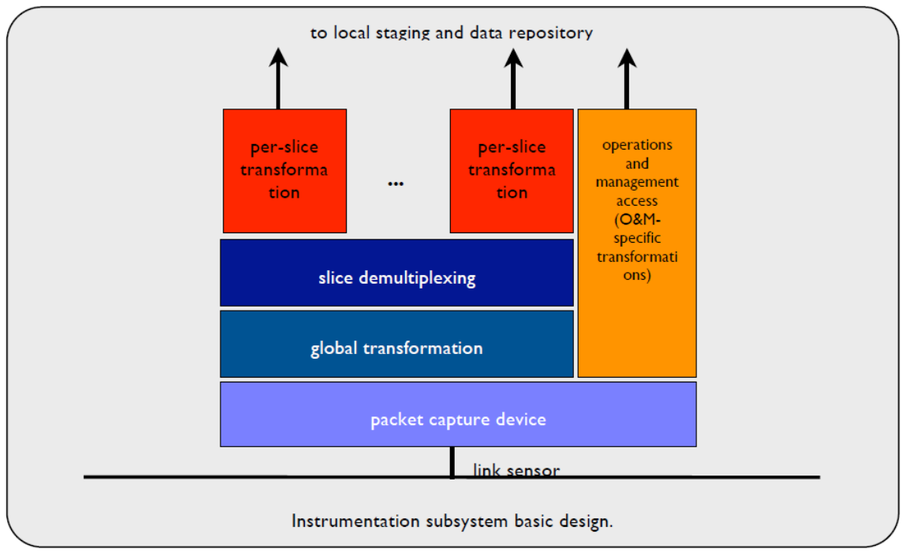


Figure 1. Basic Physical Components for Instrumentation and Measurement.



Instrumentation subsystem design block diagram.

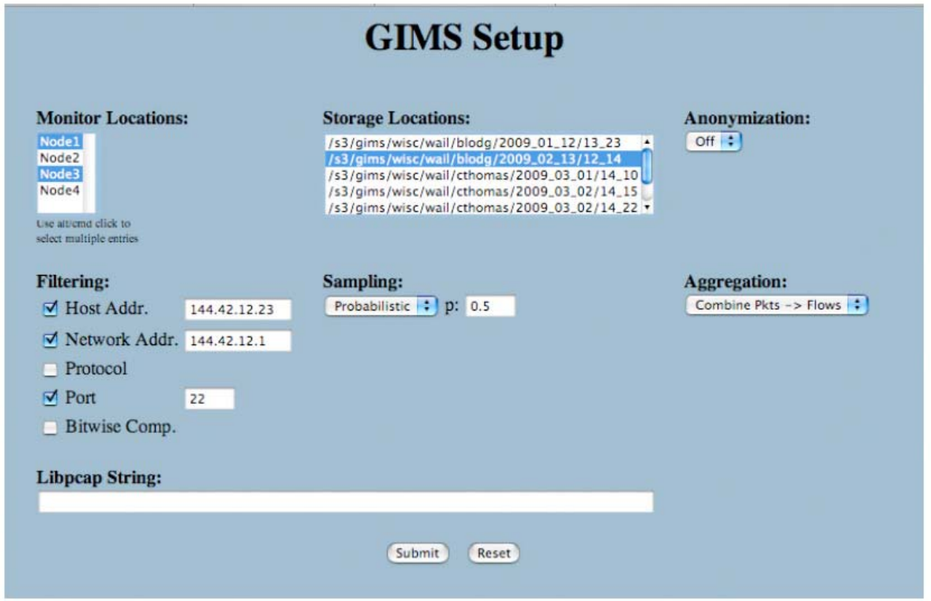
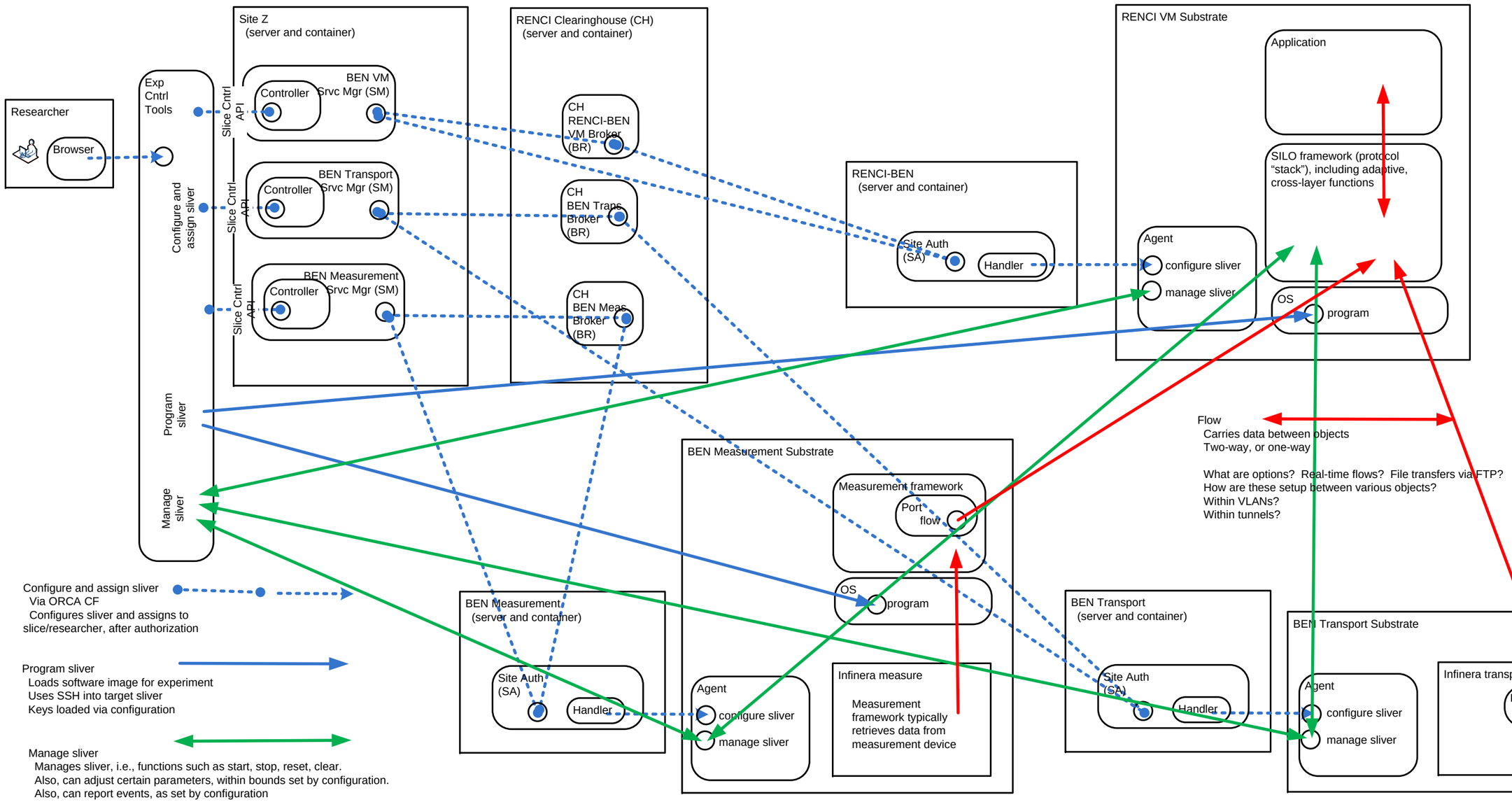


Figure 4. Mockup of GIMS UI



Configure and assign sliver
Via ORCA CF
Configures sliver and assigns to slice/researcher, after authorization

Program sliver
Loads software image for experiment
Uses SSH into target sliver
Keys loaded via configuration

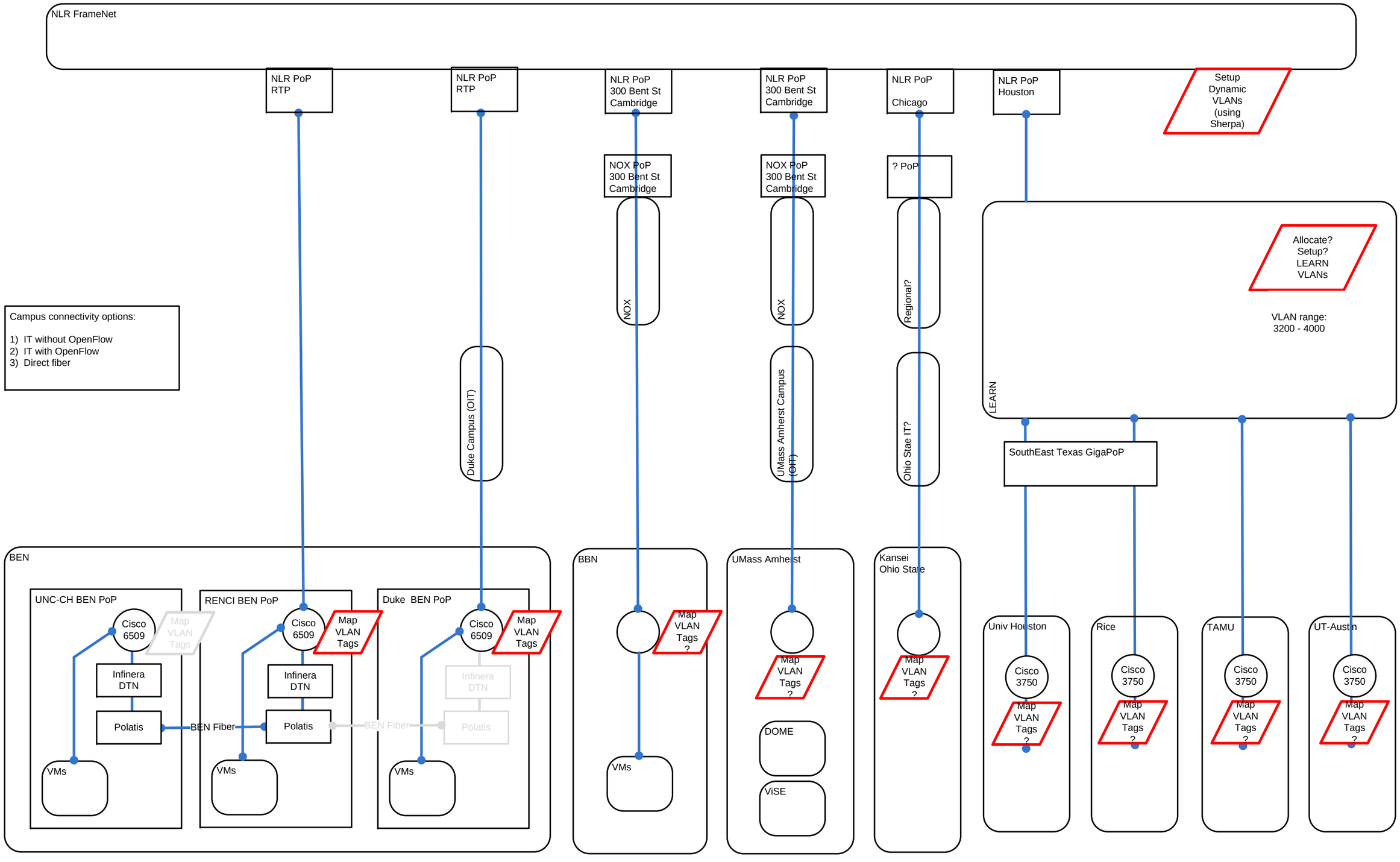
Manage sliver
Manages sliver, i.e., functions such as start, stop, reset, clear.
Also, can adjust certain parameters, within bounds set by configuration.
Also, can report events, as set by configuration

What is protocol of manage messages?
Can these messages be carried between exp cntrl tools to agent, via CF?
How can other paths be defined, i.e, between SILO and agent?

Note:
Manage interface between SILO and measurement substrate agent permits SILO to learn of events, and to set measurement parameters, i.e., a threshhold

Note:
BEN transport and measurement substrates have essentially the same interfaces.

Note:
Manage interface between SILO and transport substrate agent permits SILO to learn of events, and to set configuration parameters, i.e., to pick a port


NLR FrameNet
NLR PoP RTP
NLR PoP RTP
NLR PoP 300 Bent St Cambridge
NLR PoP 300 Bent St Cambridge
NLR PoP Chicago
NLR PoP Houston
Setup Dynamic VLANs (using Sherpa)
NOX PoP 300 Bent St Cambridge
NOX PoP 300 Bent St Cambridge
? PoP
NOX
NOX
Regional?
Allocate? Setup? LEARN VLANs
VLAN range: 3200 - 4000
LEARN
Campus connectivity options:
1) IT without OpenFlow
2) IT with OpenFlow
3) Direct fiber
Duke Campus (OIT)
UMass Amherst Campus (OIT)
Ohio Stae IT?
SouthEast Texas GigaPoP
BEN
UNC-CH BEN PoP
RENCI BEN PoP
Duke BEN PoP
Cisco 6509
Map VLAN Tags
Infinera DTN
Polatis
BEN Fiber
VMs
BBN
Map VLAN Tags ?
UMass Amherst
DOME
ViSE
Kansei Ohio State
Univ Houston
Rice
TAMU
UT-Austin
Cisco 3750