Virtual Mobile Cloud Network for Realizing Scalable, Real-Time Cyber Physical Systems

Kiran Nagaraja, Yanyong Zhang,
Ivan Seskar, Dipankar Raychaudhuri (PI)
WINLAB, Rutgers University

Kiyohide Nakauchi, Yozo Shoji (PI)
NICT

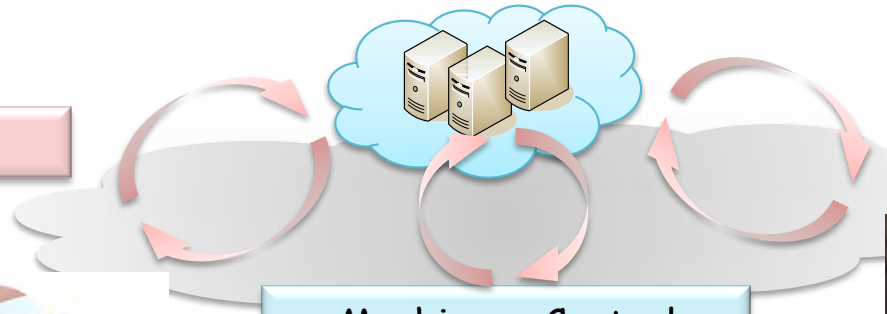
JUNO PI Meeting
June 25, 2014

Summary

- Design & Develop Virtual Mobile Cloud Network (vMCN)
  - Trillion-order scalability for CPS devices/objects
  - Less than 100 msec response time in CPS application
- WINLAB's prior works mainly for the scalability are organically integrated with NICT's prior works mainly for the real-time
- Additional research challenges related to cloud migration and virtual network design will be addressed jointly by NICT and WINLAB
- Demonstrate vMCN with a typical CPS application over GENI and JGN-X testbeds

Needs for Real-time & Scalable Cyber Physical System (CPS) are Emerging

Mobile Cloud Services



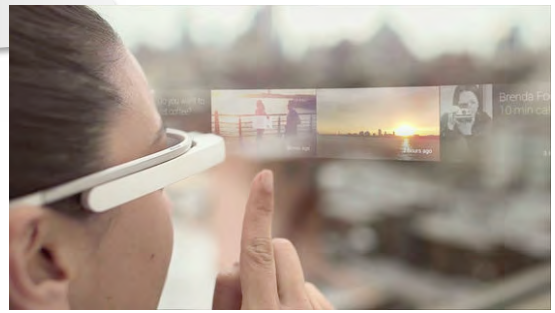
Safety

- Automatic driving
- Emergency alert

Machinery Control

- Emergency stop
- …

Emerging Services



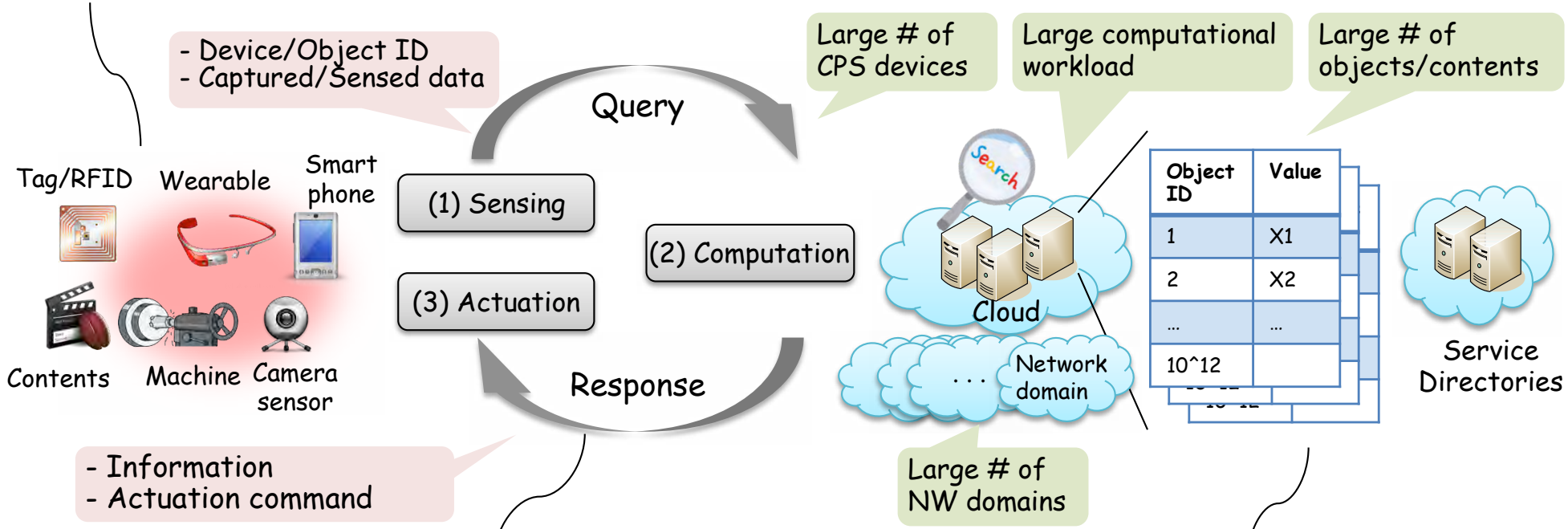
- AR navigation
- Automatic translation

Real-time response

Scalability for devices and objects

Future CPS Function Model and Requirements

■ Terminal Mobility



■ Real-time

<100msec response time in application

&

■ Scalable

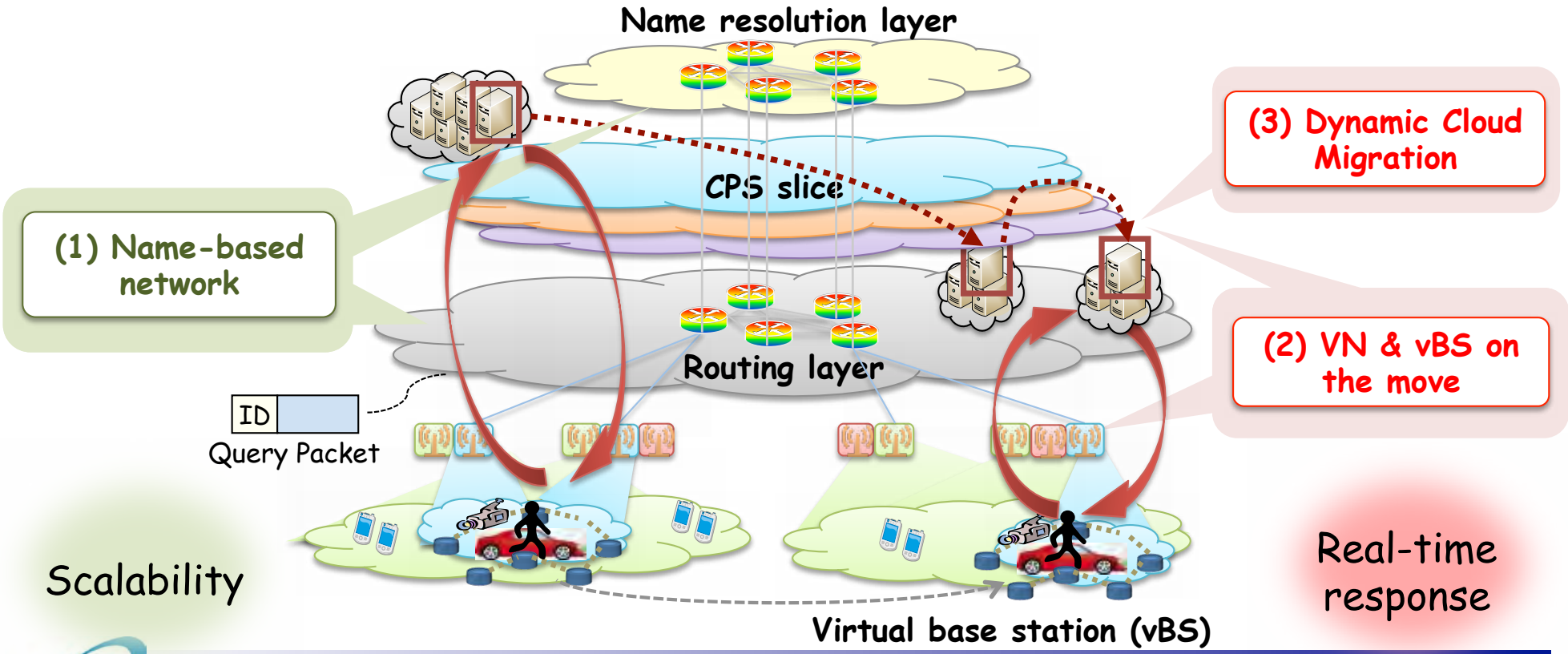
Trillion-order CPS devices & objects are properly handled

Project Goals

- Design a network architecture
  - Trillion-order scalability for CPS devices/objects
  - Less than 100 msec response time in CPS application
- Develop a proof-of-concept prototype
  - MF router software enhanced for the real-time
  - vBS software enhanced for global mobility
  - Running the prototype over GENI and JGN-X
- Demonstrate an example future CPS application
  - AR (Augmented Reality) application using glass devices

Overview of Virtual Mobile Cloud Network (vMCN)

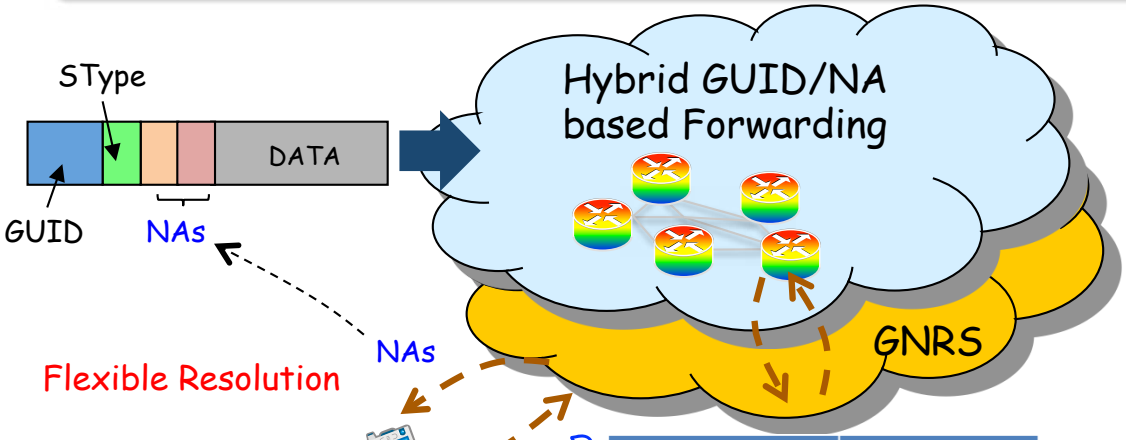
- At-scale & low-latency global name resolution ✓ Scalable
- Dynamically configurable wired and wireless resources ✓ Real-time
- Optimal placement and dynamic migration of cloud services ✓ Real-time



Technical Approach :

(1) Name-based Network

- Key MobilityFirst components
  - At-scale, low-latency global name resolution
  - Flexible and extensible hybrid GUID/NA routing
- Research issues
  - Exploiting locality to minimize name resolution costs and RTTs
    - Spatial locality-aware GNRS
  - How to provision network resources for e2e service requirements?

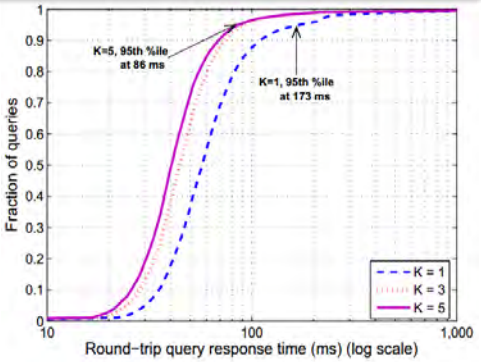


GUID	NAs
XXX345	NA1, NA2, NA3
XXX89	NA1, NA2
.....	.....

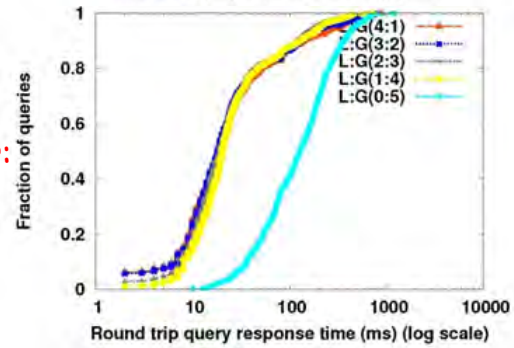
Flexible Resolution

1. Early binding
2. Late binding
3. Dynamic binding

Internet scale evaluation (26K networks): **cost of resolution < 100ms**



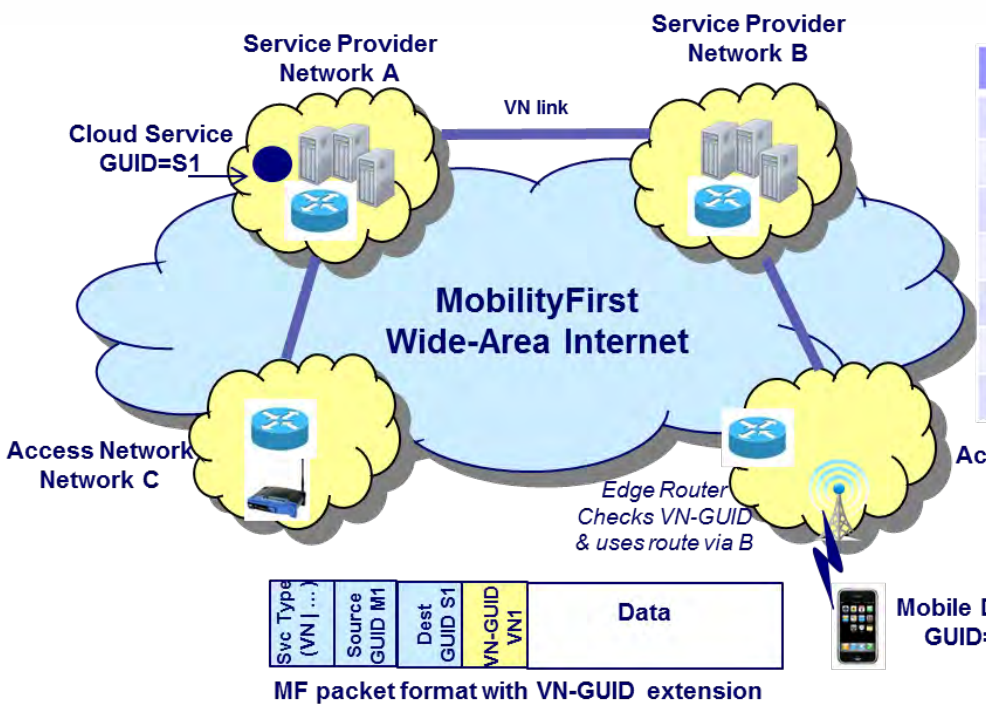
Spatial locality awareness can reduce it further: **few 10s of ms**



Technical Approach :

(2-1) Virtual Network Support in MobilityFirst

- Service-specific Virtual Network (VN)
  - GUID can be used to name end-to-end service slice
  - VN required to span network elements and end hosts
  - Extensions required for both name resolution and routing layer



Extended GNRS Entries

VN	GUID	GUIDs/NAs
N	S1	NA - A
N	M1	NA - D
Y	VN1	NA-A,B,C,D
Y	NA-A	NA-B,C
Y	NA-B	NA-A,D
Y	NA-C	NA-A
Y	NA-D	NA-B

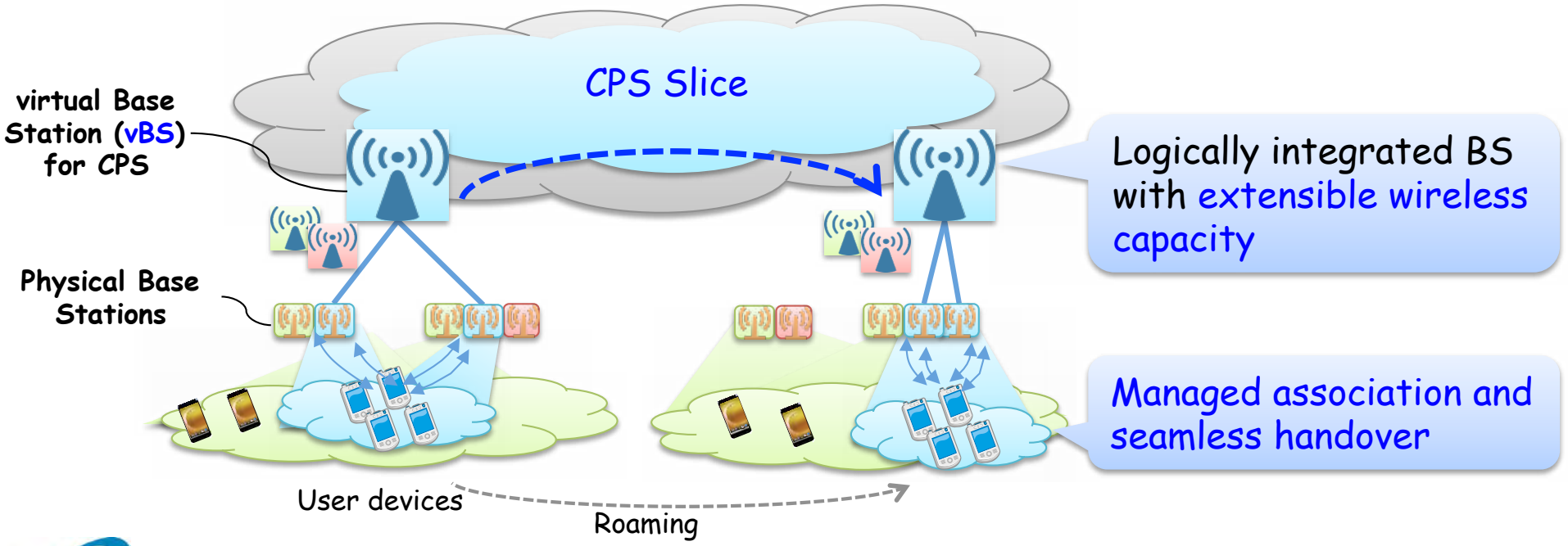
GNRS mappings can capture VN membership and access control

How do we dynamically provision wireless resources for VN?

Technical Approach :

(2-2) Virtual Base Station (vBS) on the move

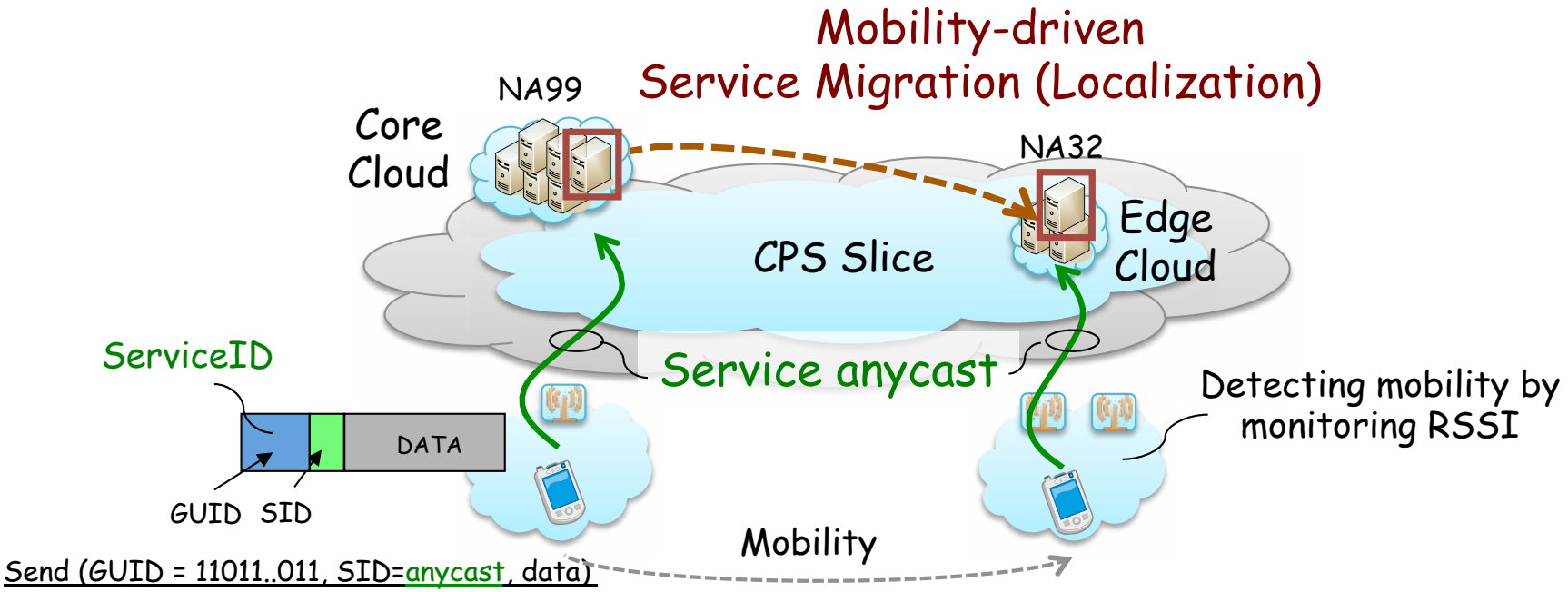
- Key vBS components
  - Dynamically provisioning physical BS resources for target applications
  - Adaptation to mobility in a "local" domain
- Research issue
  - When and where physical BS resource should be provisioned in global mobility?



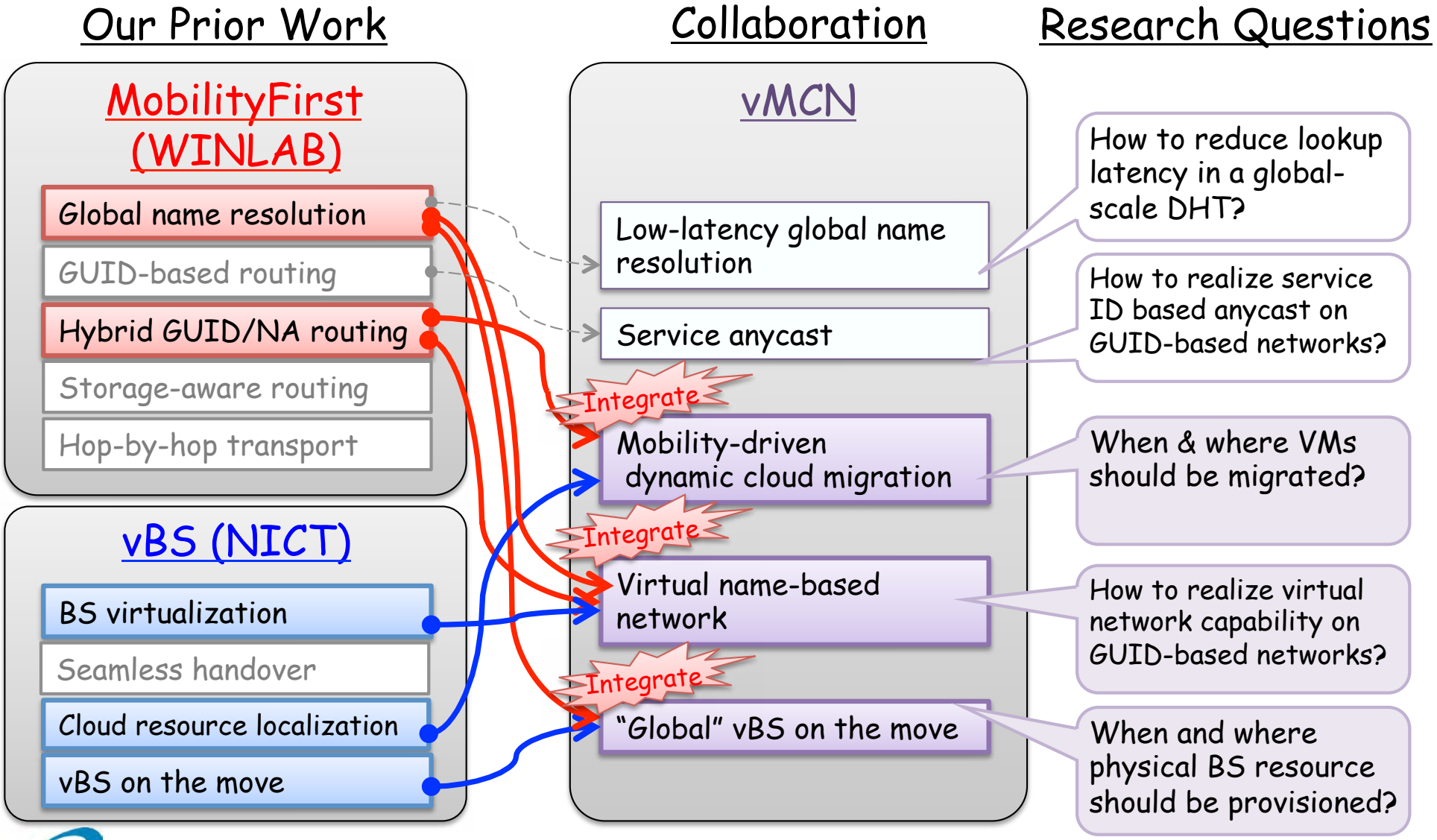
Technical Approach :

(3) Dynamic Cloud Migration

- Key components
  - Service placement and migration for quick response in CPS application
  - Routing adaptation and service continuity
- Research issues
  - Optimization algorithms for VM placement and migration
  - Anycast routing approaches for dynamic cloud services

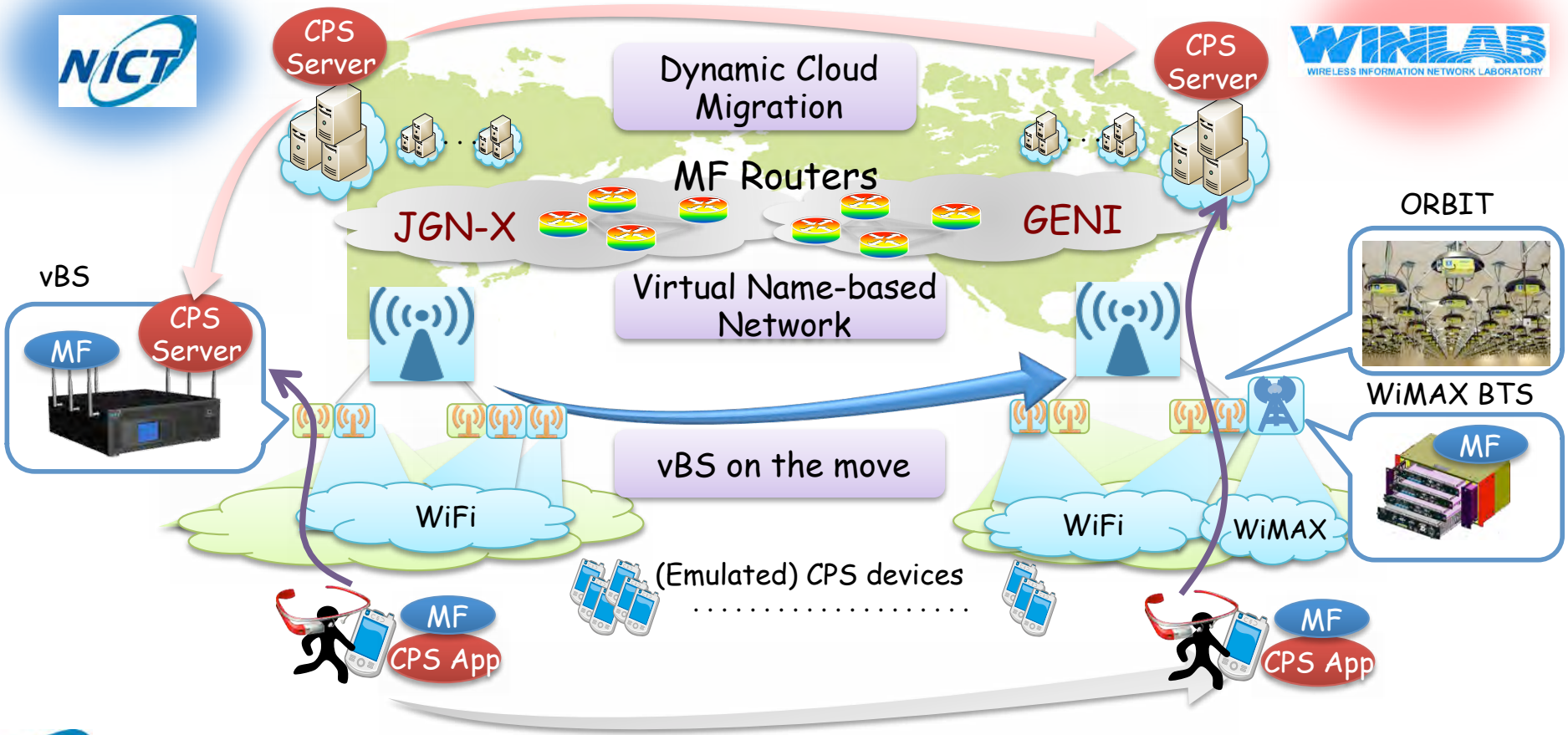


Why and How We Collaborate?: Specific Design Issues and Research Questions



Final Demonstration Image

- (Performance Goal) response time is less than 100msec for 10^6 queries/sec
- (Function Goal) CPS slices can be built over US-JP wide-area MobilityFirst network
- (Application Goal) AR service w/ glass devices over a proof-of-concept prototype

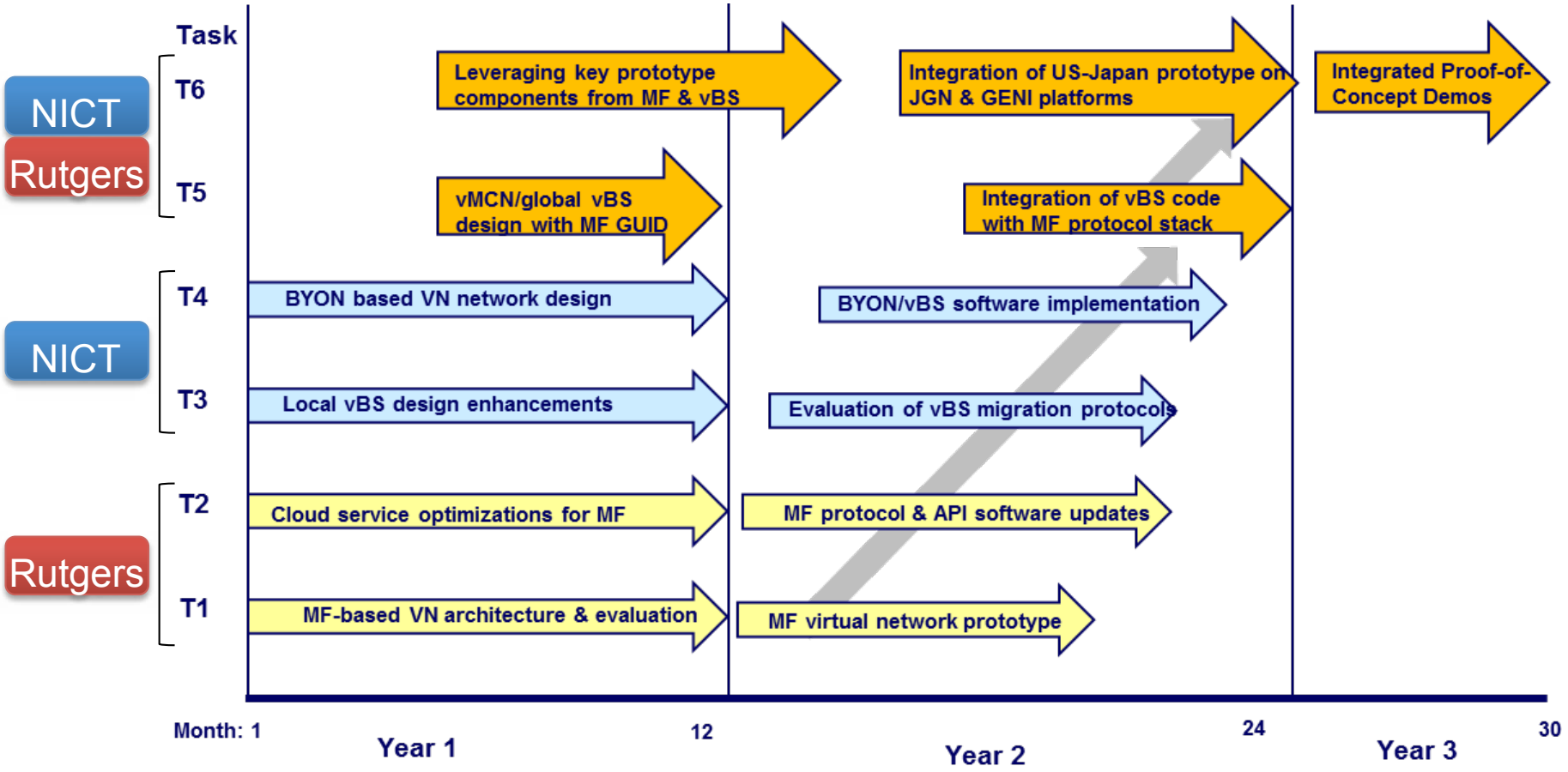


Summary

- Design & Develop Virtual Mobile Cloud Network (vMCN)
  - Trillion-order scalability for CPS devices/objects
  - Less than 100 msec response time in CPS application
- WINLAB's prior works mainly for the scalability are organically integrated with NICT's prior works mainly for the real-time
- Additional research challenges related to cloud migration and virtual network design will be addressed jointly by NICT and WINLAB
- Demonstrate vMCN with a typical CPS application over GENI and JGN-X testbeds

APPENDIX

Milestones


Task
NICT
Rutgers
T6
T5
NICT
T4
T3
Rutgers
T2
T1
Leveraging key prototype components from MF & vBS
Integration of US-Japan prototype on JGN & GENI platforms
Integrated Proof-of-Concept Demos
vMCN/global vBS design with MF GUID
Integration of vBS code with MF protocol stack
BYON based VN network design
BYON/vBS software implementation
Local vBS design enhancements
Evaluation of vBS migration protocols
Cloud service optimizations for MF
MF protocol & API software updates
MF-based VN architecture & evaluation
MF virtual network prototype
Month: 1
12
24
30
Year 1
Year 2
Year 3

Deliverables

Project Task	Responsible Groups	Year 1 Deliverables	Year 2 Deliverables	Year 3 Deliverables (6 months)
T.1. MF-based virtual network architecture & protocol implementation	WINLAB	Design and preliminary evaluation; software prototype; testing on ORBIT SDN sandbox	MF/VN software implementation and integration with MF Click & OpenFlow s/w	Version update
T2. MF optimizations for cloud service including GNRS speed-up & cloud migration	WINLAB	Optimization of MF services (anycast, context, compute) for cloud service and GNRS speed-up via caching etc.	Upgrade to MF code release including service API; GNRS extensions and integration	----
T.3. Local vBS design enhancements and latency reduction	NICT	Design and evaluation of state transfer method for local VN	implementation of vBS migration protocols and algorithm in BYON prototype	----
T4. BYON-based virtual network design and implementation	NICT	Design and preliminary evaluation; BYON-API for vBS and cloud migration; testing on BYON prototype	vBS software implementation and integration with BYON OpenFlow base station	Version update
T.5. vMCN/Global vBS on the move design, integrated with MF GUID services	NICT and WINLAB	Integrated design of BYON/vBS and MF/VN; Evaluation of GUID-based method for global VN	Integration of vBS's code with MF protocol stack; global area cloud migration prototype	Version update
T.6. Proof-of-concept vMCN system prototyping & application demos	NICT and WINLAB	Preparing/leveraging key components: MF protocol stack, GNRS, VN extensions, vBS extensions, AR app, etc.	Integration of US-Japan prototype on GENI and JGN; application testing; system performance studies	Integrated proof-of-concept demos& CPS application trials