2018 Japan-US Network Opportunity 2 (JUNO2)

Project Title: *Disaster-Resiliency Strategies for Next-Generation Metro Optical Networks*

ATN: 1818972

Speakers:

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Project Team

- **PIs**
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  - Yoshinari Awaji; NICT (Japan); Team leader (PI Japan side)
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  - Yusuke Hirota; NICT (Japan); Collaborator
  - Masaki Shiraiwa; NICT (Japan); Collaborator
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Motivation

A new generation of optical metro networks is needed to turn the vision of "Smart Cities" into reality

- Future metro networks: from a rigid ring-based aggregation infrastructure to a composite network-and-computing ecosystem to support critical 5G services (e.g., autonomous driving)

- Several technical enablers:
  - Increased reconfigurability enabled by **SDN**
  - **Integration of optical and wireless** access networks
  - Metro nodes becoming edge data centers (**edge computing**)
  - **Network slicing** to logically partition network, computing, and storage resources
  - …

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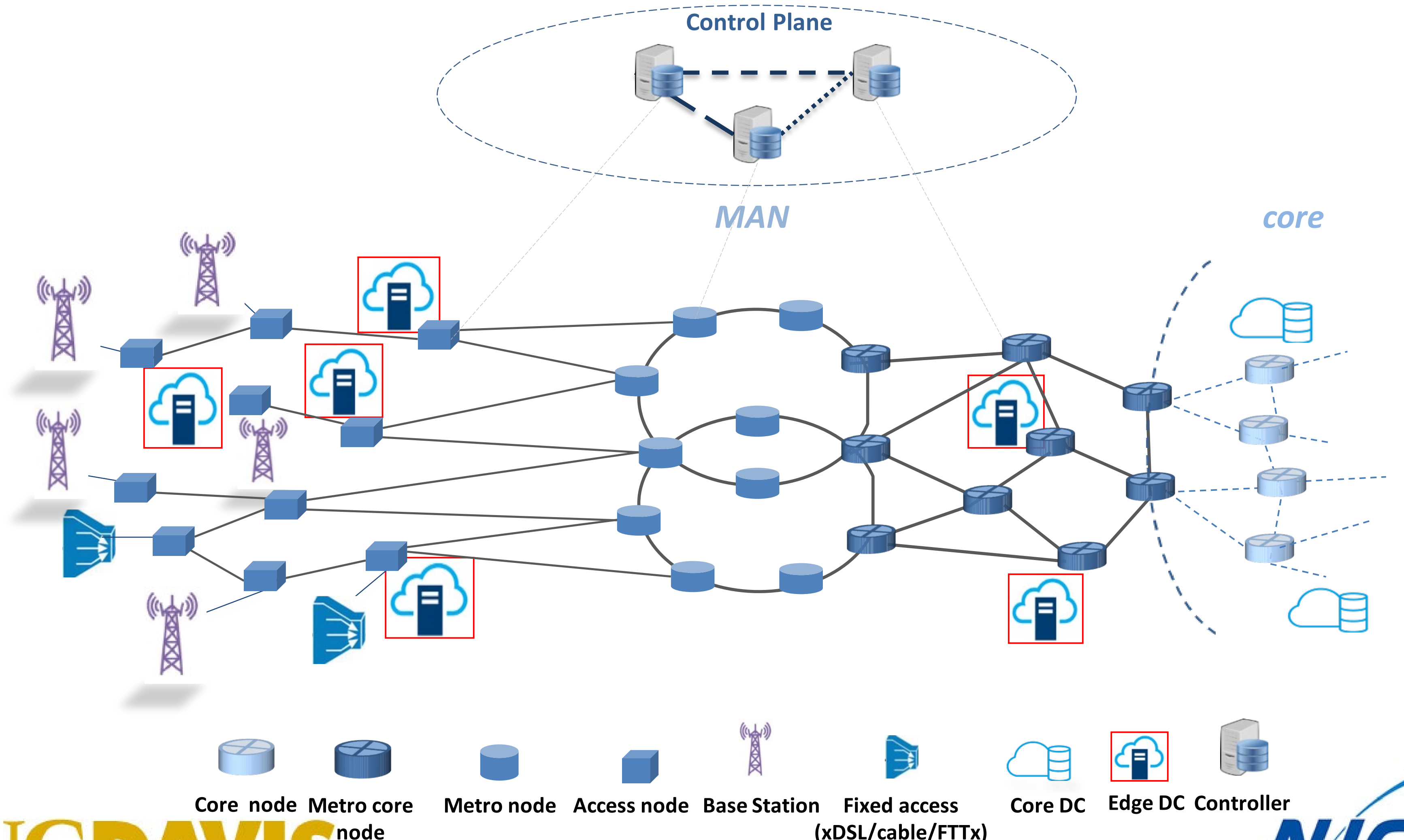
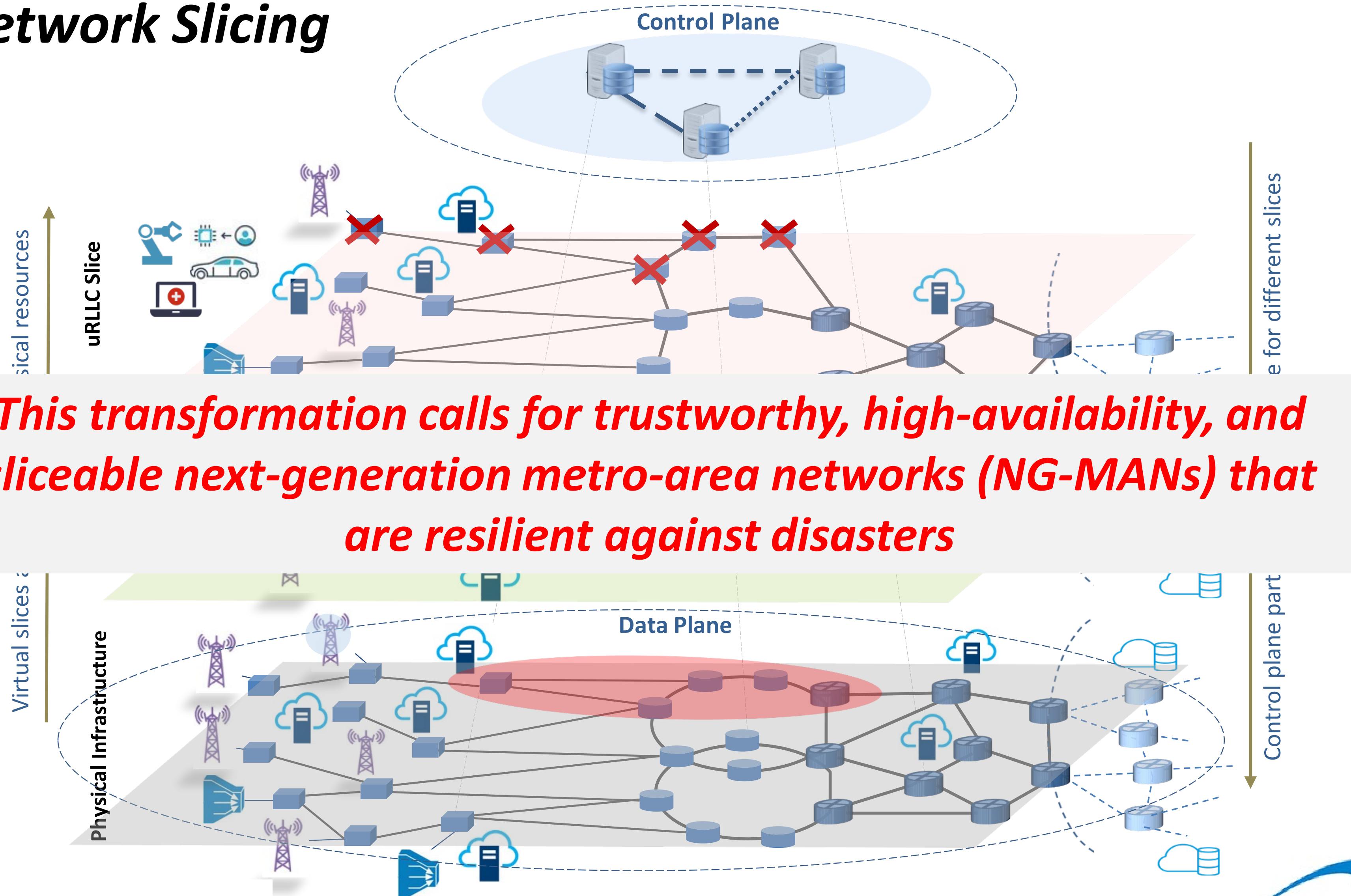
Evolution of Metro Access Networks (I)

Edge computing and SDN



Evolution of Metro Access Networks (II)

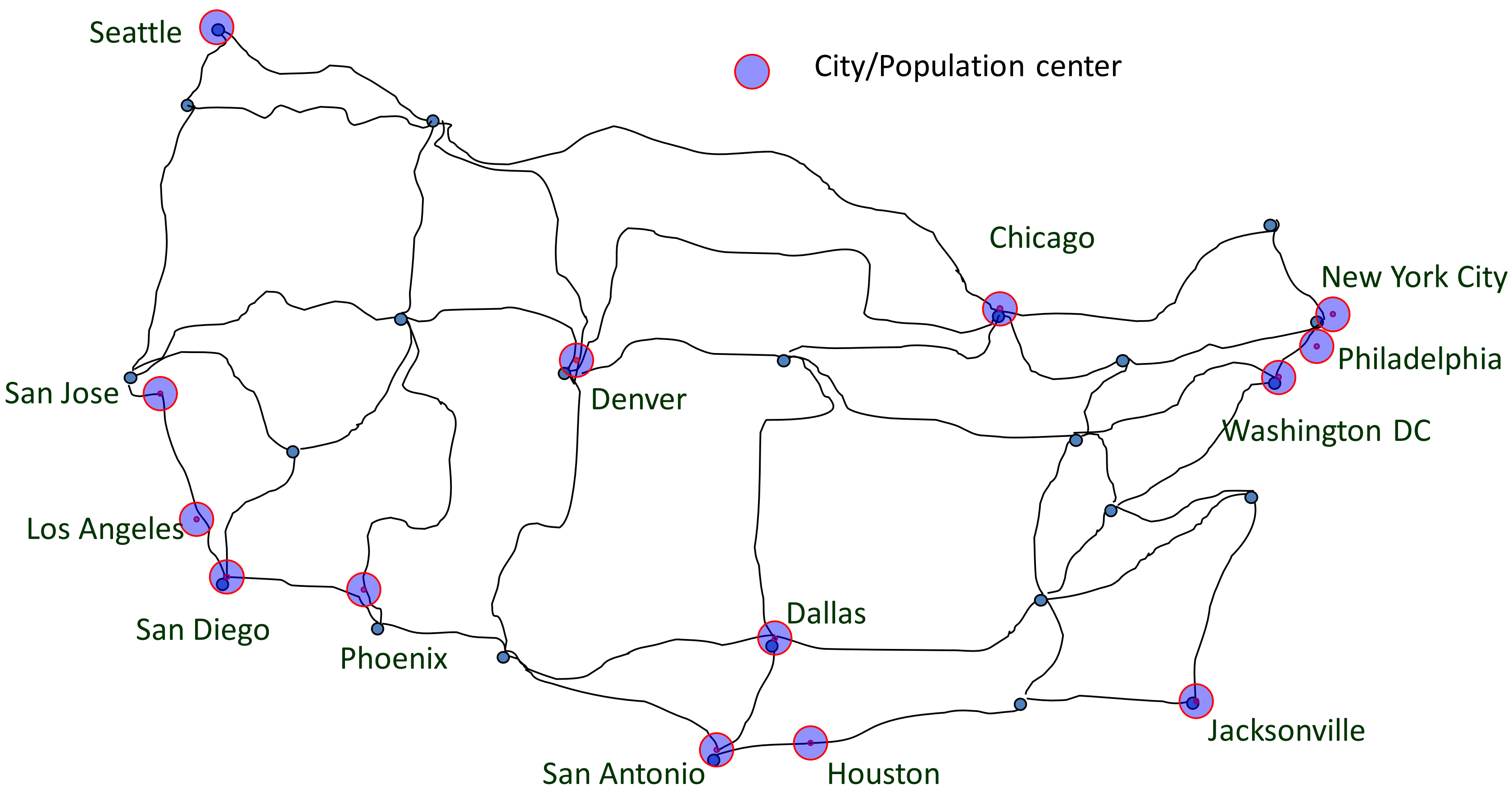
Network Slicing



This transformation calls for trustworthy, high-availability, and sliceable next-generation metro-area networks (NG-MANs) that are resilient against disasters

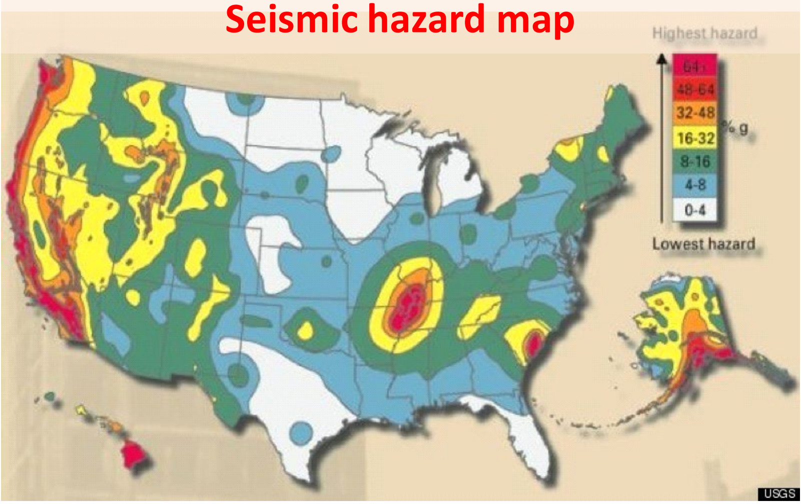
Disaster affecting underlying NG-MAN

Traditional Core Optical Network

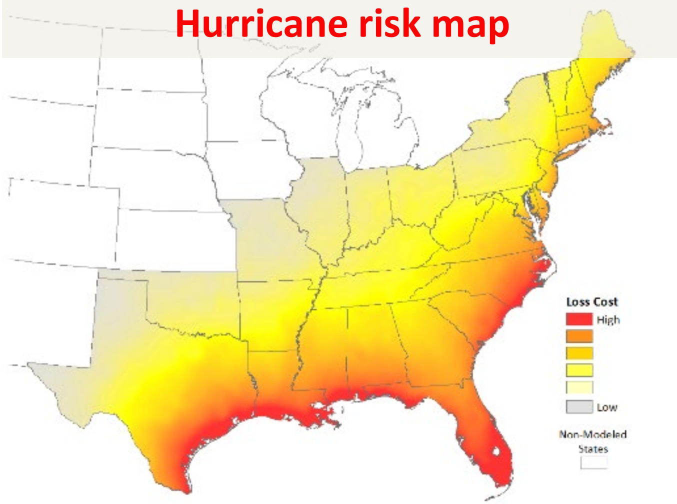


Disaster Maps

Seismic hazard map

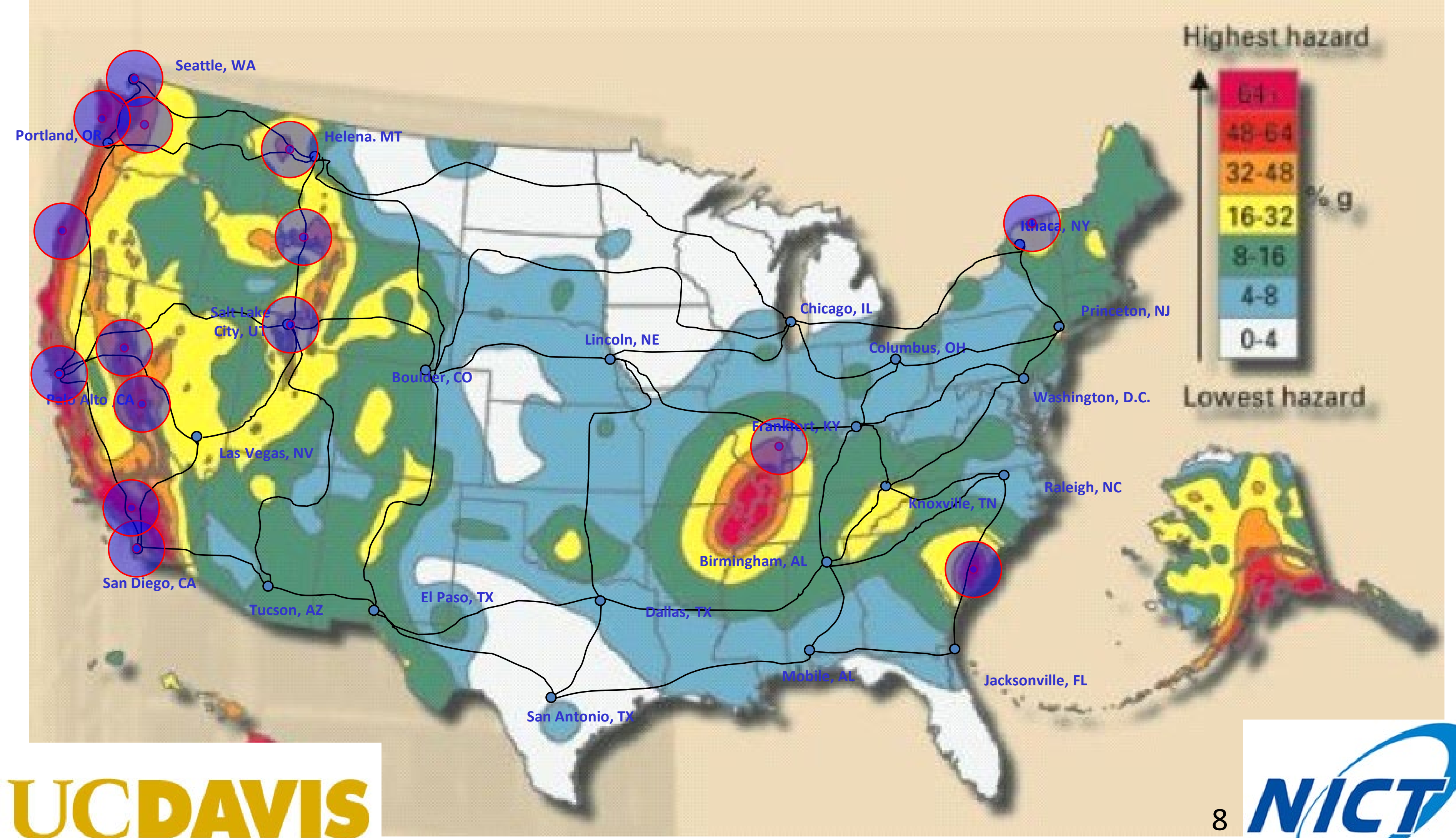


Hurricane risk map



Risk maps **of such disasters can be obtained and matched with the *physical topology of a network* to help design a disaster-resilient network.**

Determination of Disaster Zones



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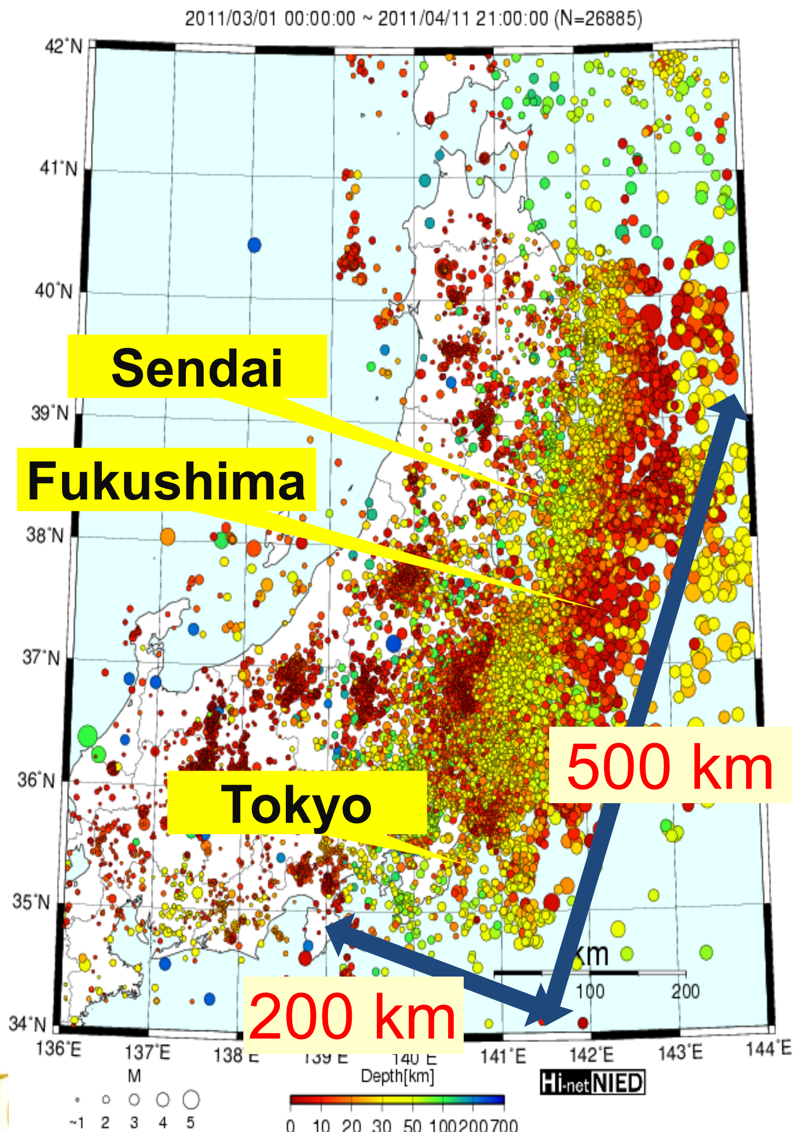
Recent crisis – Disasters in Japan



Types of Failure/breakdown

- General (common) types of failure/breakdown
  - Interface failures
  - Link failures
  - Node failures
  - Misconfigurations

- Failures/breakdown depends on optical communication networks
  - QoT degradation, throughput degradation, increasing electrical buffering delay

- Failures/breakdown in disaster
  - Power blackout
  - Fiber-cut
  - Contact damage by quake

⇨ Redundancy of equipment needs expensive cost.
In a disaster case, redundancy against normal equipment failures is insufficient.

Impact of Disaster-Resilient NG-MAN

- Repair communication network ASAP
  - Prompt and accurate grasp of information of damaged area
  - Immediately create reconstruction plan and execute it.

People

Life saving: It can reduce victims
Safety confirmation: Psychological care of people inside and outside the disaster area

Society

Protection of property (especially information database)
Maintain critical network services
Reconstruction of economic society

Other ripple effects

Maintaining national strength
Prevent the decline of brand power of country/region (damage on rumor)

- Rapid recovery such as communication environment of disaster area
- Continuation of social life in areas other than afflicted areas

Motivation

How we protect metro optical network from disaster?
What should we prepare for disaster resiliency?

Difficult to obtain latest information on affected areas.
Difficult to appropriately distribute/assign resources
Increase psychological burden of disaster victims
Anxiety redundancy of unaffected people

Power loss
features' failure
Fiber cut
etc.

+

Road closed
Lack of repair workers
High cost

Current Technologies

- Satellite communication
- Mobile telecommunication station

After disaster, communication is disconnected.
It takes longer time to repair optical fiber communications.

Motivation: To realize a metro optical network that can quickly restore disaster-areas and maintain normal network services outside the affected areas.

Construction of robust control network, rapid failure detection, emergency restoration of optical networks, development of portable optical devices for disaster restoration

Towards Future Disaster-Resilient NG-MAN

High-reliable Disaster Resiliency = Pre-disaster Prevention and Preparedness + Post-disaster Fast recovery

Network layer survivability

Service layer survivability

Physical layer survivability

Theme 1

Disaster-resilient SDN Control Plane

To mitigate direct damage from disaster

Theme 2

Slice Protection for a Disaster-resilient Data Plane

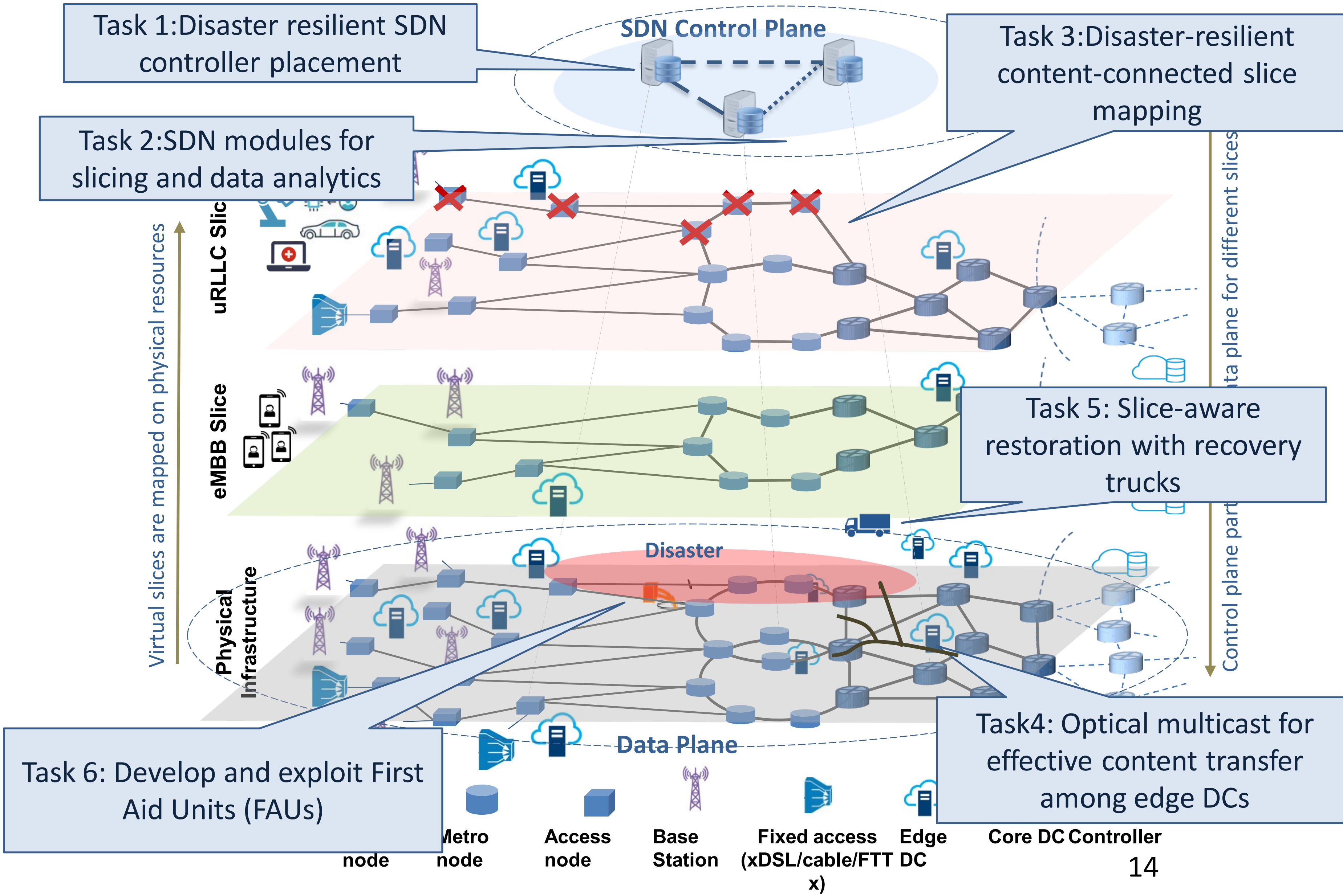
To withstand disaster

Theme 3

Rapid Recovery via Movable Network Devices

To restore optical network temporary as soon as possible

Project Overview (1)

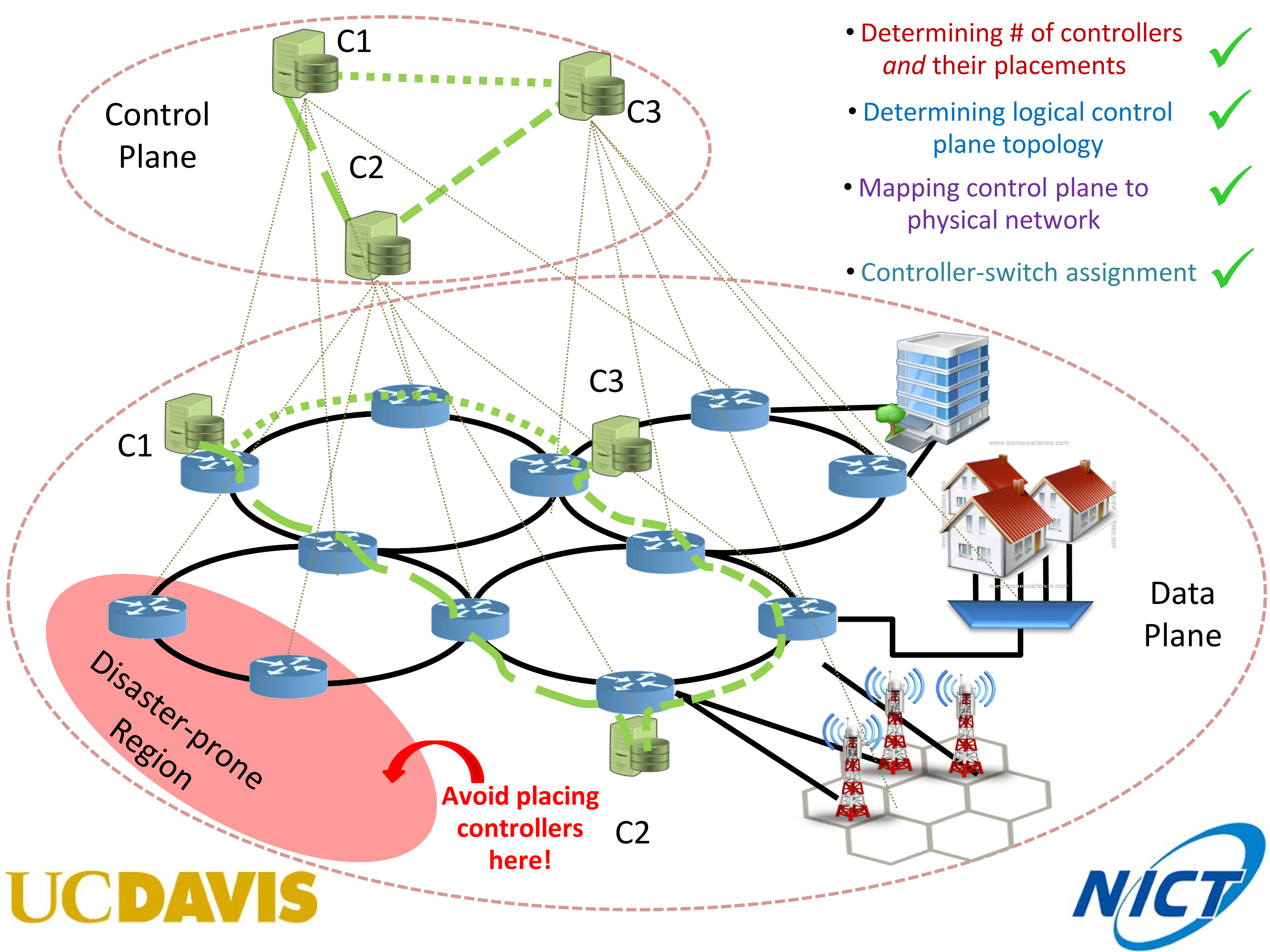


Overall Topics

	Disaster-resilient NG-MANs		
Phase	Pre-disaster phase		Post-disaster phase
Theme	<u>Theme 1: Prevention</u> Disaster-resilient design of the SDN control plane	<u>Theme 2: Preparedness</u> Protection strategies for sliceable NG-MANs	<u>Theme 3: Fast recovery</u> Recovery strategies with portable devices in NG-MANs
Target	AI-assisted Control plane survivability	Content-centric D-plane survivability	Emergency restoration for physical layer survivability
UC Davis	Task 1 Disaster-resilient SDN controller placement	Task 3 Disaster-resilient content-connected slice mapping	Task 5 Slice-aware restoration with recovery trucks for NG-MAN
NICT	Task 2 SDN modules for network slicing and data analytics	Task 4 Optical multicast for effective content transfer among edge DCs	Task 6 Develop and exploit First Aid Unit (FAU)
Key technologies	SDN/NFV, Machine learning	Flexible grid & multicast transmission	Novel portable/movable disaster recovery systems

Task 1: Disaster-Resilient SDN Controller Placement in NG-MANs

- Making the control plane resilient means introducing redundancy through distributed controllers
  - *How many controllers?*
  - *Where to place them?*
  - *Consider delay, survivability, capacity requirements, synchronization overhead, etc.*


• Determining # of controllers *and* their placements
• Determining logical control plane topology
• Mapping control plane to physical network
• Controller-switch assignment
Control Plane
C1
C2
C3
Data Plane
C1
C2
C3
Disaster-prone Region
Avoid placing controllers here!
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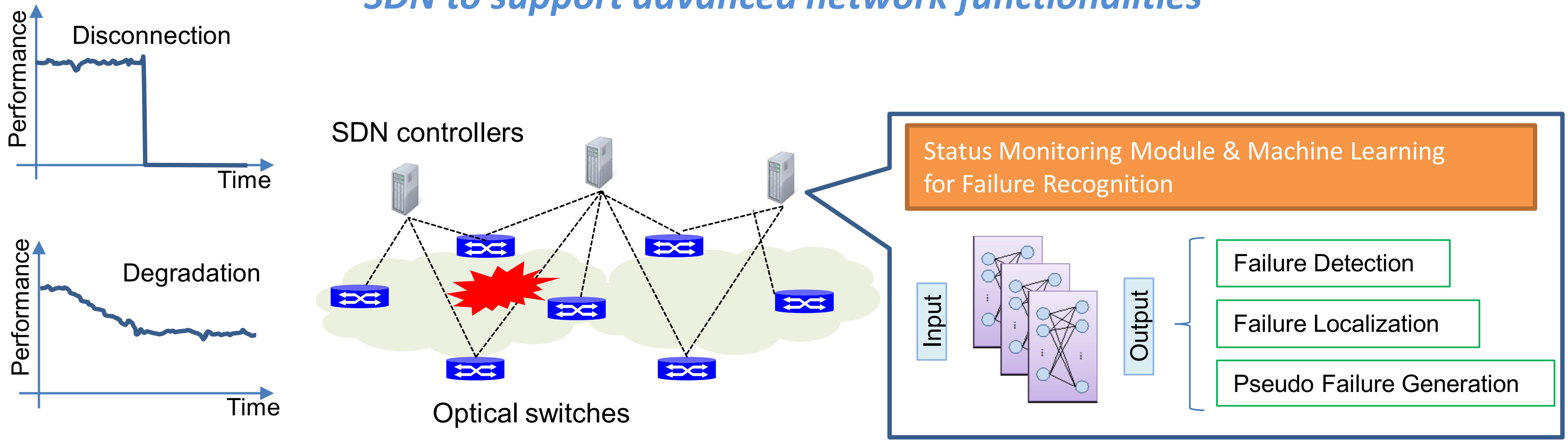
Task 2: SDN Modules for Network Slicing and Data Analytics

Theme: Disaster-resilient design of SDN control plane

SDN to support advanced network functionalities



- ***SDN Control Plane and Slicing***: Assignment of SDN controllers to slices with different requirements - how one or multiple controllers can manage different slices (e.g., one controller per slice or multiple slices per controller).
- ***SDN-Based monitoring for Detecting Failures***: Failure detection mechanisms that make use of the global network view provided by SDN to promptly correlate disaster failures.
  - Detection mechanism for disconnected links and failed nodes
  - Machine Learning based failure recognition mechanisms for incomplete network connectivity

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Task 2: SDN Modules for Network Slicing and Data Analytics

- Topic 2-1: （Support advanced network functionalities）
  - How to collect D-plane information and manage slices.
    - Prepare evaluation model
- Topic 2-2: （Suppress performance degradation)
  - How to detect/localize various failures in NG-MANs?
  - How to collect Training Data?
    - LLDP or ML based Failure Recognition approaches
    - Pseudo failure generation
- Goal:
  - With the distributed SDN controllers, perform the resilient slice management, and, failure detection and analytics ⇨ Support advanced network functionalities, quick response to failures suppressing performance degradation

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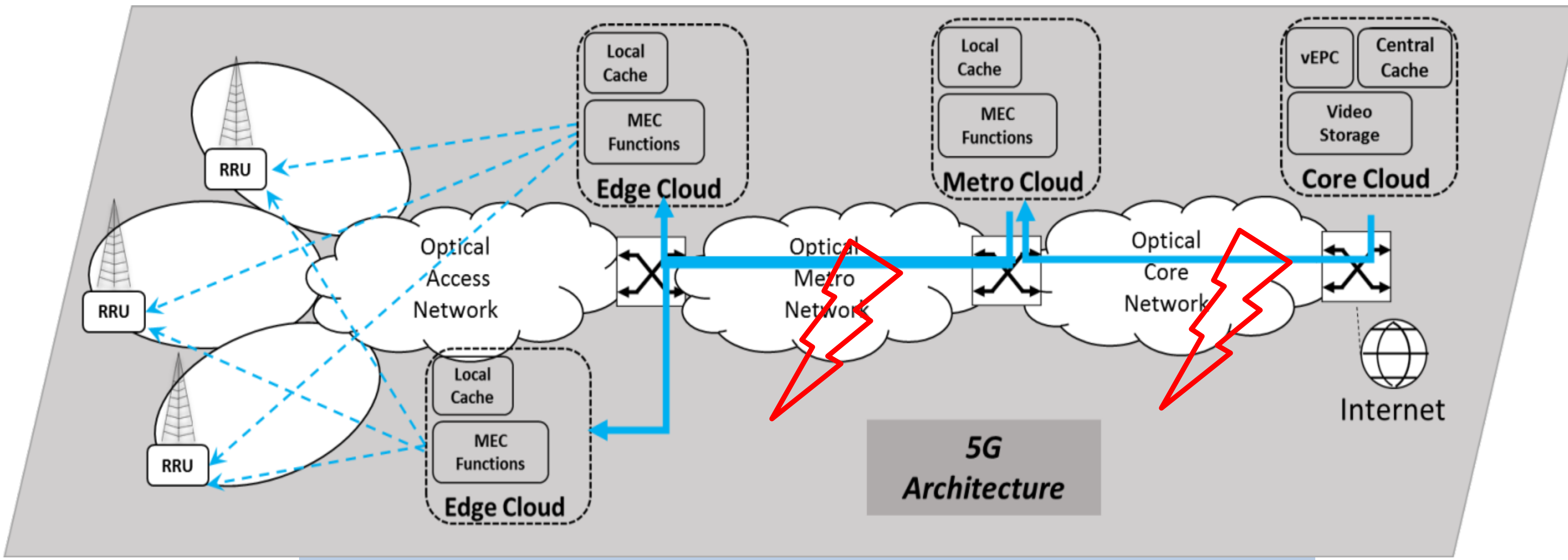
Intro to Theme 2
From Cloud to Edge Computing

- How to guarantee 99,999(9)% service availability [1] in 5G
  - Enabler: Fog/Edge Computing, Mobile Edge Computing (MEC)

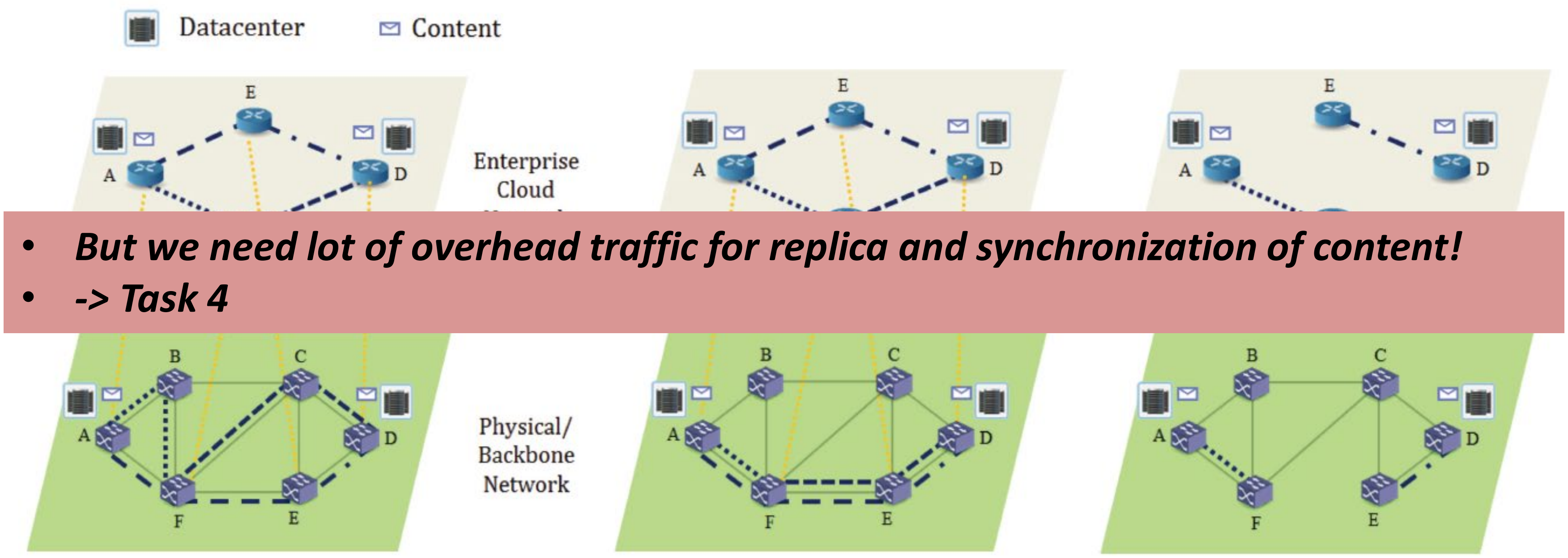
Several cloud services can be replicated and accessed even in case of network disconnection!



[1] NGMN Alliance "5G white paper." *Next generation mobile networks, white paper* (2015).

Task 3: “Content Connectivity” for Disaster Resiliency in NG-MANs

Content Connectivity - ensure reachability of content from any point of a network (end-to-content) even in case of a disaster partitioning the network



- ***But we need lot of overhead traffic for replica and synchronization of content!***
- ***-> Task 4***

Task 4: Optical Multicast for Effective Content Transfer among Edge DCs

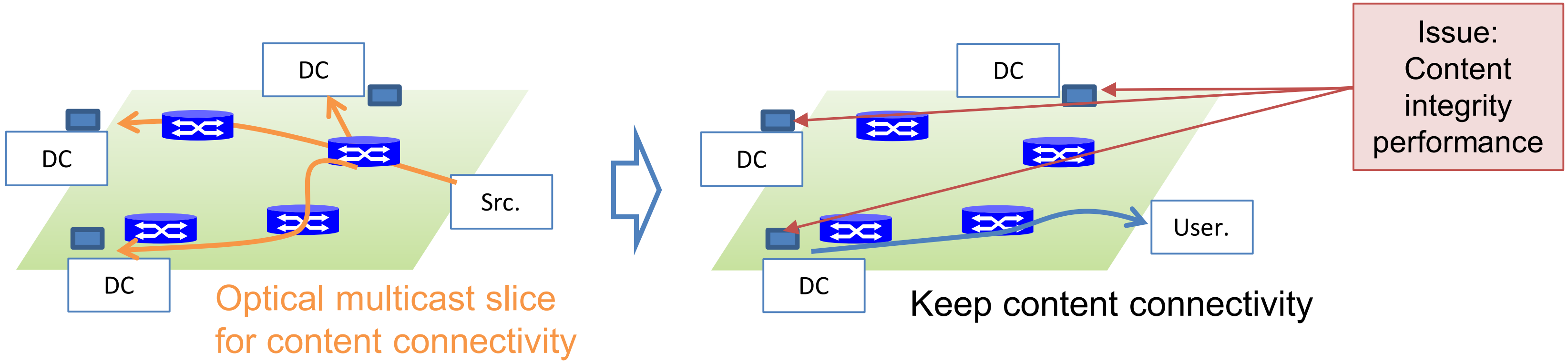
"Content connectivity" can be realized only if relevant data is replicated in several edge DCs

- *Constant and intensive synchronization and backup procedures among edge DCs via optical multicasting (Verification on OPCI network testbed)*

- ***Selection of multicast tree leaves for disaster resiliency*** - How do we determine which nodes receive the synchronization data of the multicast tree?
- ***Slicing and multicasting*** - How to slice network resources for multicast transmissions?
- ***Verification of optical multicasting with SDN control in Sendai testbed*** - SDN controllers need to monitor transmitted data and to construct multicasting slices considering the locations of edge DCs.

OPCI network testbed @Sendai NICT branch

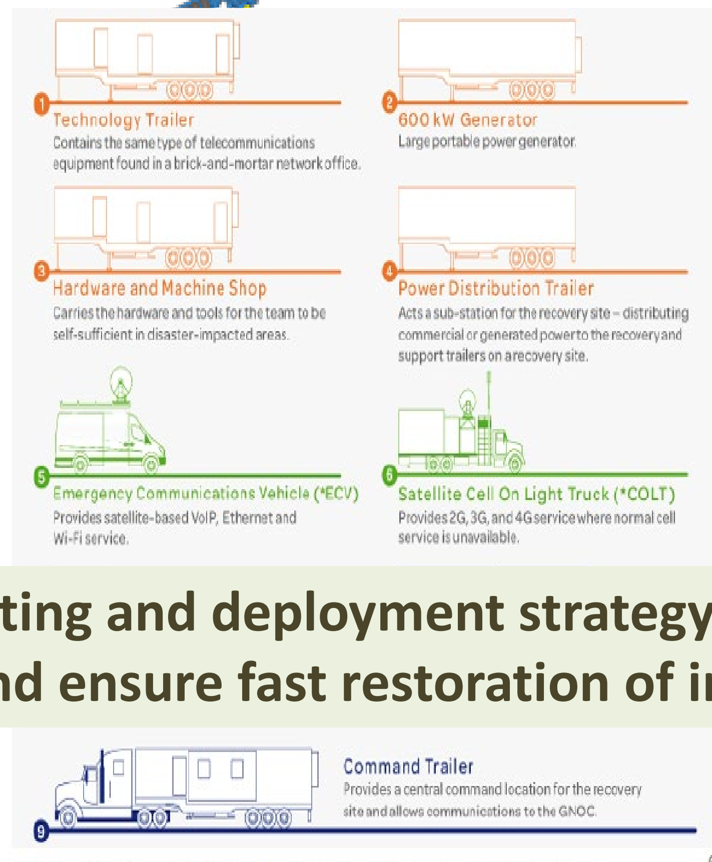
Task 4: Optical Multicast for Effective Content Transfer among Edge DCs



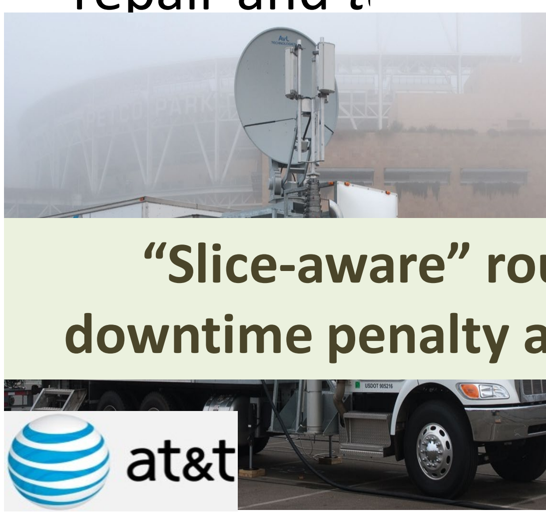
- Topic 4-1: （Efficient data replication via optical multicasting ）
  - Multicast slicing and load balancing
- Topic 4-2: （Verification over OPCI network testbed)
  - Experiment of optical multicasting @ Sendai testbed
    - Verify the content connectivity maintenance in case of network failures
  - Verify distributed content integrity with optical multicast.

Task 5: Slice-Aware Service Restoration with Recovery Trucks for NG-MANs (I)

Rapid net ... nits



- In the post ... ide both repair and t ... going on



"Slice-aware" routing and deployment strategy to minimize downtime penalty and ensure fast restoration of important slices.

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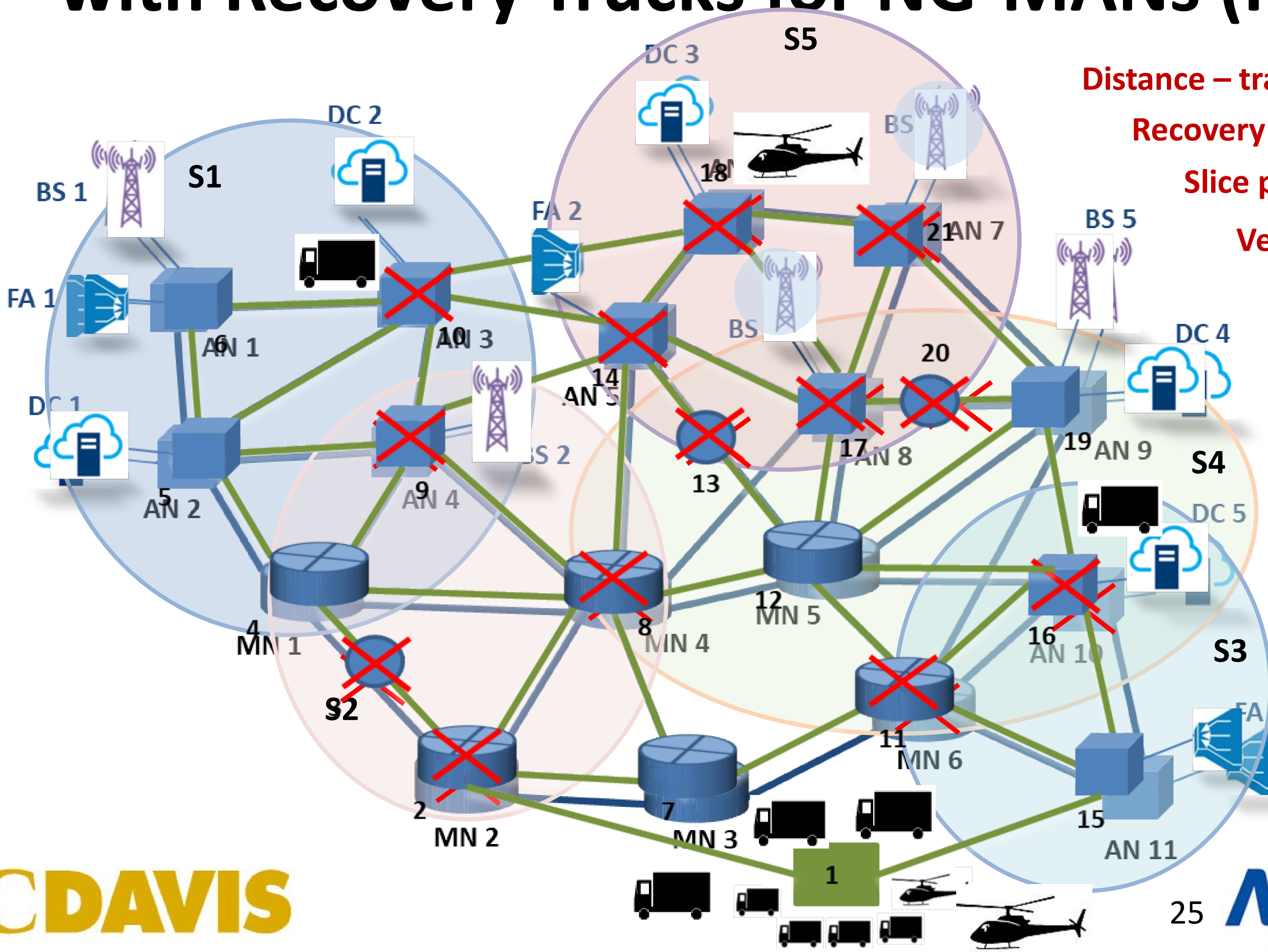
Task 5: Slice-Aware Service Restoration with Recovery Trucks for NG-MANs (II)



Distance – travel time

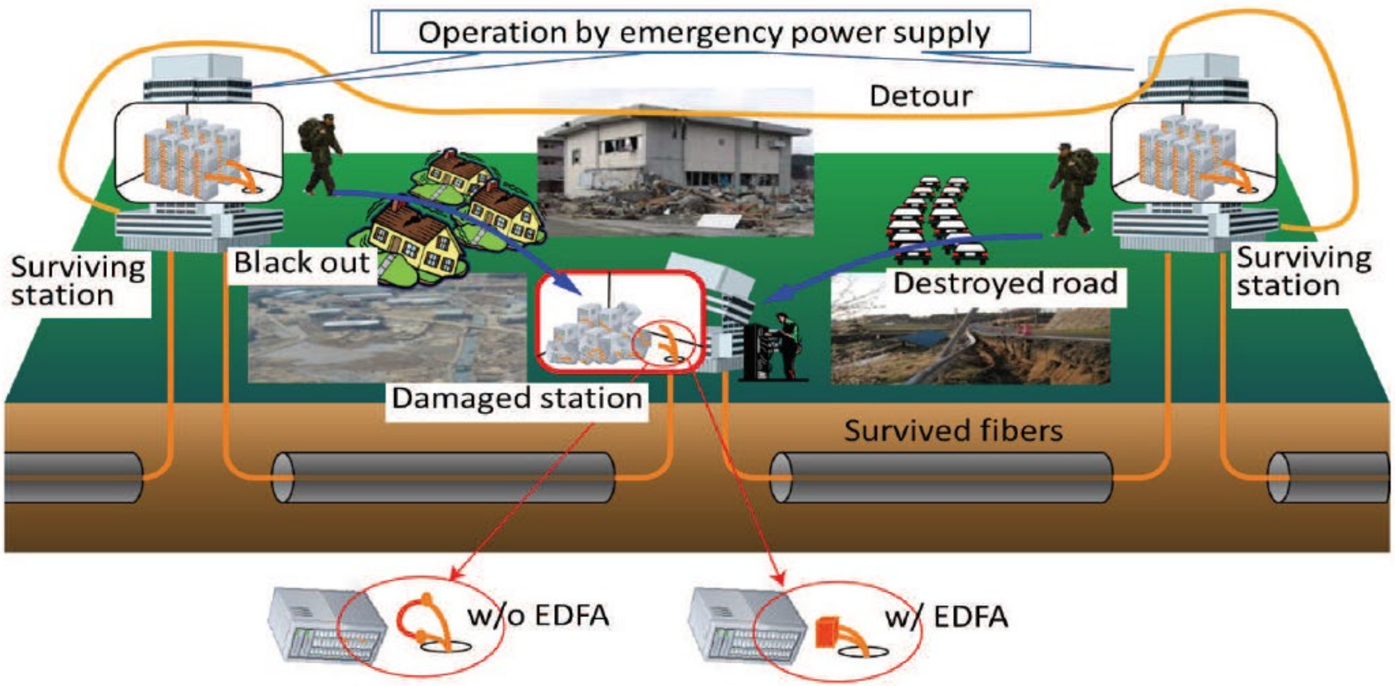
Recovery time

Slice priority

Vehicle type

Task 6: Develop and exploit First Aid Unit (FAU)

Interconnection of surviving facilities and FAU to restore network connectivity



- *Impairment information collection utilizing monitoring systems*
- *Impairment-aware emergency optical network planning*
- *Development of supportive hardware and control system*

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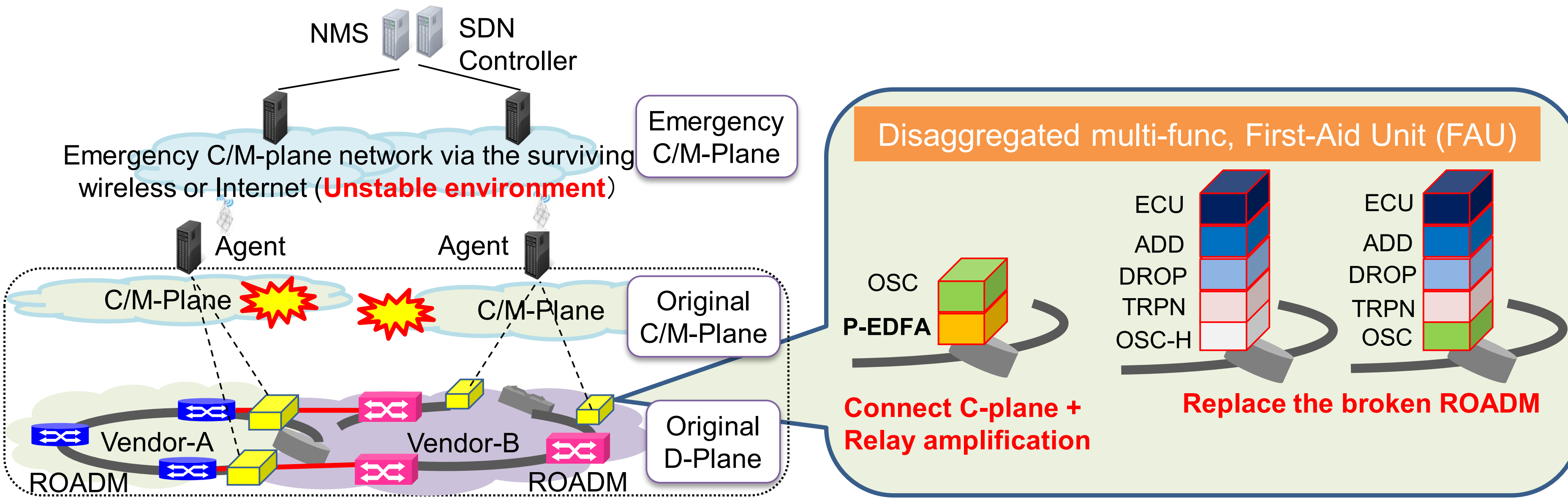
Task 6: Develop and exploit First Aid Unit (FAU)

Interconnection of surviving facilities and FAU to restore network connectivity



Surviving optical network resources, e.g., ROADM, fibers

+

Emergency resources, e.g., FAUs

- *Impairment information collection utilizing monitoring systems*
- *Impairment-aware emergency optical network planning*
- *Development of supportive hardware and control system*

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Task 6: Develop and exploit First Aid Unit (FAU)

- Topic 6-1: *Impairment information collection*
  - Employ emergency optical performance monitoring (OPM) subsystem in FAU
  - Create emergency telemetry platform using outside surviving network resources (e.g., wireless/Internet)

- Topic 6-2: *Impairment-aware emergency optical network planning*
  - Optimization of portable EDFA placement
  - Optimization of the surviving multi-vendor network interconnection

- Topic 6-3: *FAU upgrade*
  - Portable EDFA (C- and L-band)
  - External optical supervisory channel (OSC) unit
  - Disaggregated functions from ROADM
  - Other communication link (LTE/satellite etc.)

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Integration (I)

- Complementary expertise
  - Dr. Awaji and Dr. Xu, and Dr. Shiraiwa have long-term R&D experience on optical resilient communication systems
  - Dr. Hirota brings expertise in future network and optical network architecture
  - Dr. Tornatore has extensive research experience in network flow optimization and traffic engineering
  - Dr. Mukherjee brings expertise on optical network design and survivability

- Research exchanges

- Sendai testbed
  - Data generation (for AI) and solution verification (for UCDavis design approaches)

Integration (II)

- **Integrated US and Japan Team responsibilities (per task)**
  - Dr. Tornatore and Mukherjee: Tasks 1, 3 and 5
  - Dr. Awaji: Tasks 2, 4 and 6

  - Practical examples of research integration (a summary):
    - Task 1-2: UC Davis will investigate how to design a disaster-resilient SDN control plane, and NICT will cover the following operational aspects (e.g., forecast traffic intensity and requirements)
    - Task 3-4: UC Davis will provide estimation of synchronization and backup traffic for content connectivity. Based on such inputs, NICT will investigate optical multicast trees inter-DC data synchronization leveraging SDN testbed in Sendai
    - Task 5-6: Common topic is "Post-disaster recovery mechanisms involving movable recovery units". UCDavis on scheduling aspects, NICT on FAU development of the units

Thank you for your attention!

Gantt chart

<table>
<tr><th align="right">Duration</th><th colspan="3">Year 1</th><th colspan="3">Year 2</th><th colspan="3">Year 3</th></tr>
<tr><td>Task #
Months</td><td>4</td><td>8</td><td>12</td><td>16</td><td>20</td><td>24</td><td>28</td><td>32</td><td>36</td></tr>
<tr><td>1: Disaster-resilient SDN controller placement</td><td bgcolor="gray"></td><td bgcolor="gray"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2: SDN modules for network slicing and data analytics</td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3: Algorithms for dis.-resilient content-connected slice mapping</td><td></td><td></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td></td><td></td></tr>
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<tr><td>6: Deployment planning and development of portable burst-mode optical amplifiers</td><td></td><td></td><td></td><td></td><td></td><td></td><td bgcolor="gray"></td><td bgcolor="gray"></td><td bgcolor="gray"></td></tr>
<tr><td>Progress Reports (J is to JST and X is to NSF)</td><td>J</td><td></td><td>X</td><td>J</td><td></td><td>X</td><td>J</td><td></td><td>XJ</td></tr>
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