IEEE Globecom 2019

December 11, 2019

Slice-Aware Service Restoration with Recovery Trucks for Optical Metro-Access Networks

Sifat Ferdousi[1], Massimo Tornatore[1,2], Sugang Xu[3], Yoshinari Awaji[3], and Biswanath Mukherjee[1]

[1]University of California, Davis, USA [2]Politecnico di Milano, Italy [3]National Institute of Information and Communications Technology, Japan

Session: ONS3: *Intelligent Optical Networks*

Introduction

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

- 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
  - …

UC DAVIS UNIVERSITY OF CALIFORNIA

Metro-Access Networks

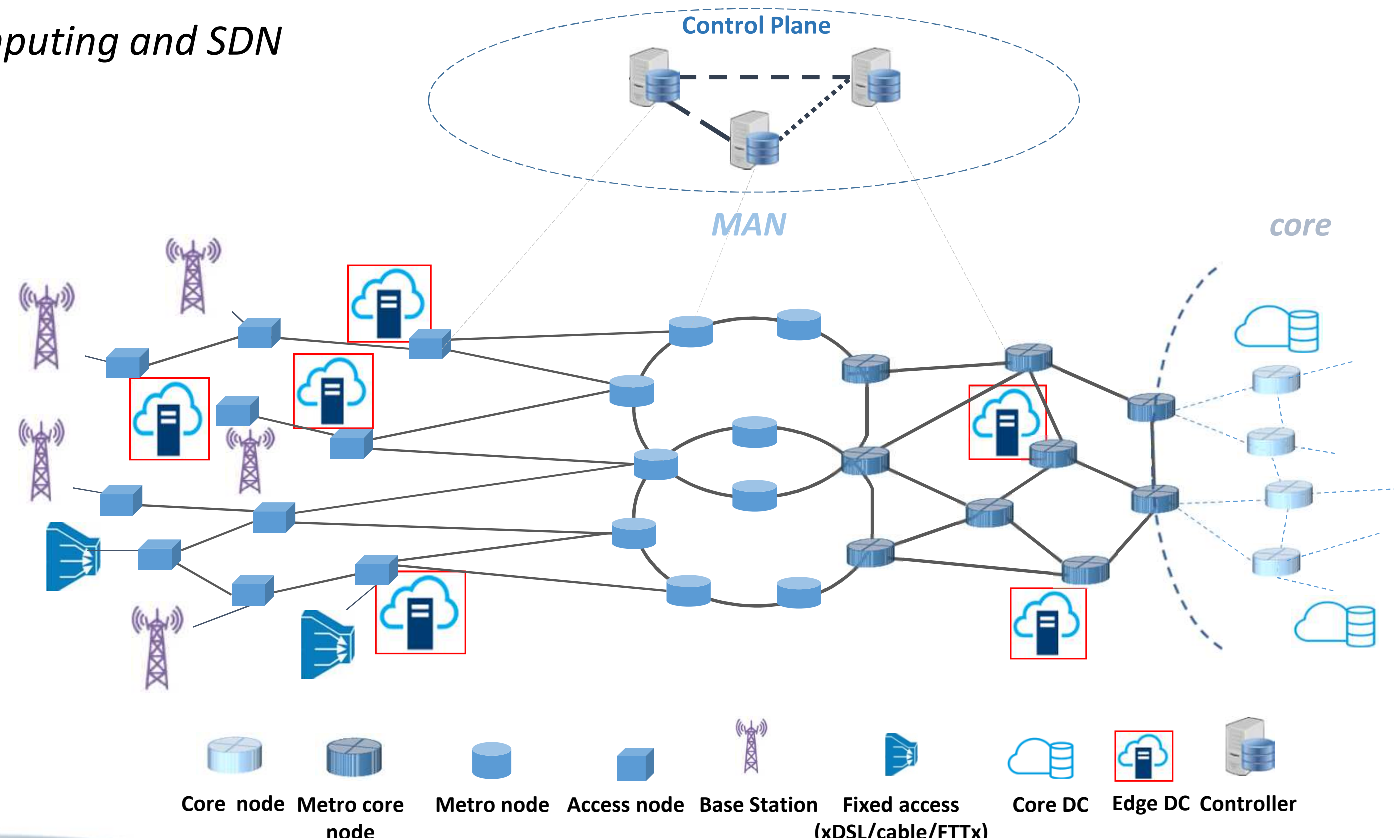
- 75% of total metro traffic is terminated within the metro network, as video, data and web content is increasingly generated at the metro networks
  - edge cloud [central office re-architected as a datacenter (CORD)]

- Metro-access networks enable heterogeneous access via both wireless and fixed network technologies – expected to support for next-generation 5G services
  - **Network slices**: end-to-end application-centric virtual networks
  - computing, storage, transport, VNFs resources from components in access, transport, core, and edge networks
  - service requirements
  - SDN programmability and re-configurability

UCDAVIS
UNIVERSITY OF CALIFORNIA

Evolution of Metro-Access Networks

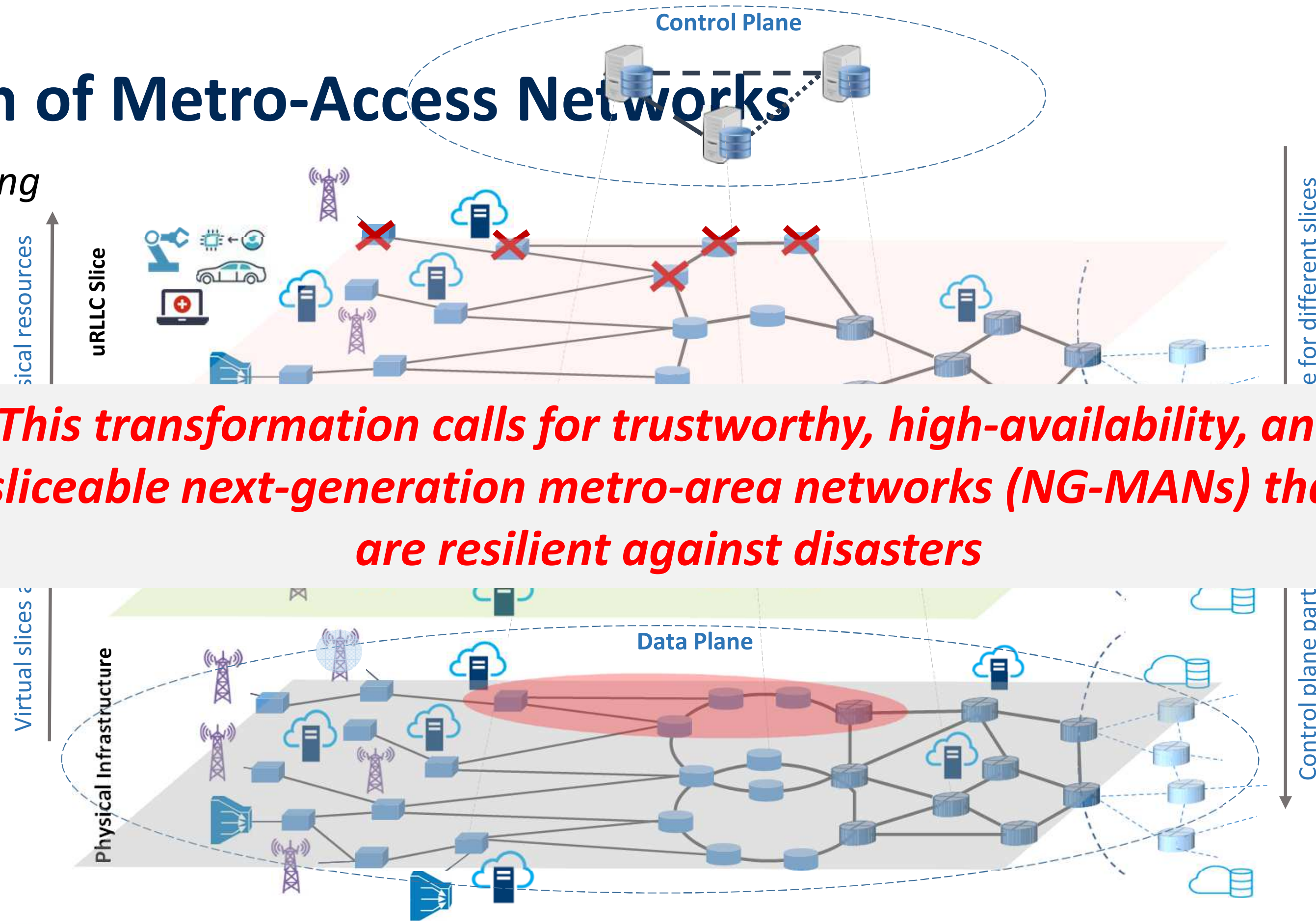
Edge computing and SDN



UC DAVIS
UNIVERSITY OF CALIFORNIA

Evolution of Metro-Access Networks

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

Types of Failure/breakdown

Post-disaster recovery

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

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

- Failures/brea
  - Power blackout
  - Fiber-cut
  - Contact damage by quake

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.

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

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

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

Recovery for Metro-Access Networks

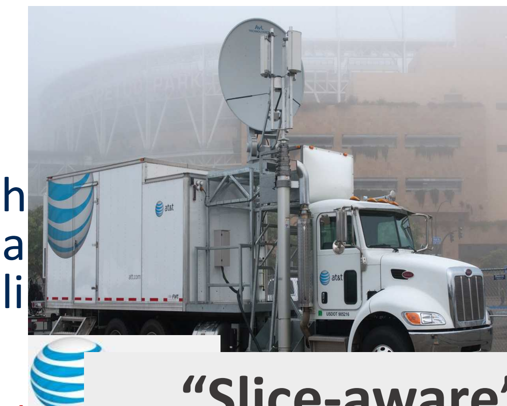
- Post-disaster recovery in metro access is different from that in core networks
  - Too expensive for disaster resiliency
  - *Much less redundant than core*

- After disaster, utmost priority: minimize service downtime (recover network asap)
  - Slice re-provisioning may not be possible with available resources and considering locality of services
  - Control plane managing the slices can also be affected by disasters

Utilize equipment for "temporary relief/service" only in case of disaster instead of preplanning lot of redundant capacity

UC DAVIS
UNIVERSITY OF CALIFORNIA

Some examples of deployable recovery units (e.g., recovery trucks, FAUs)?



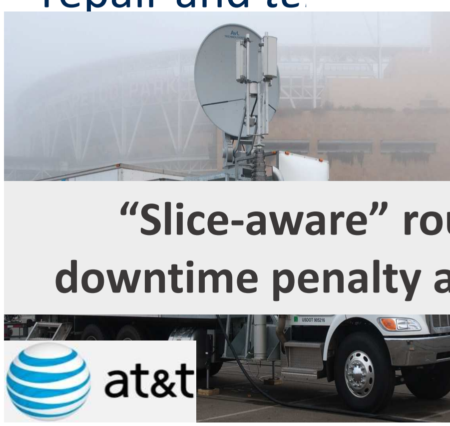
- In th ecovery truc repa *service* while g on (unli overy)
  - *How*
  - *Whe*
  - *Whe*

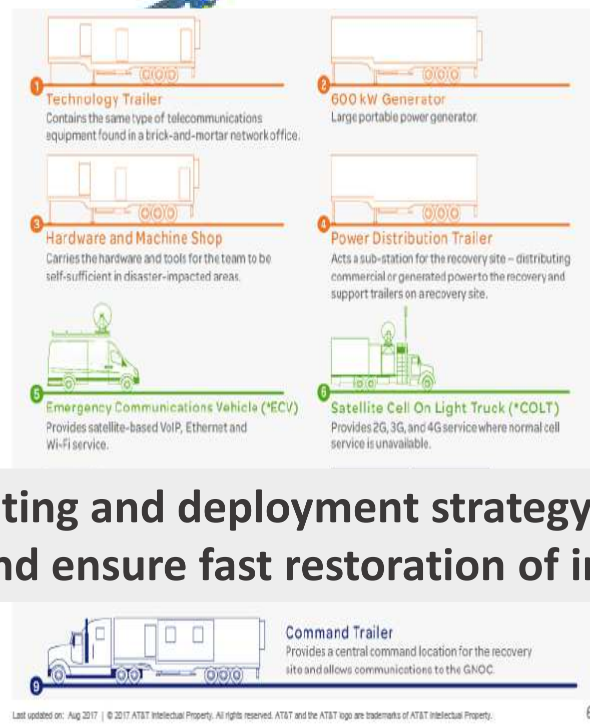
"Slice-aware" routing and deployment strategy to minimize downtime penalty and ensure fast restoration of important slices

UCDAVIS UNIVERSITY OF CALIFORNIA

Rapid net … units

- In the post-d … oth
  repair and *te* … oing on




1 Technology Trailer
Contains the same type of telecommunications equipment found in a brick-and-mortar network office.

2 600 kW Generator
Large portable power generator.

3 Hardware and Machine Shop
Carries the hardware and tools for the team to be self-sufficient in disaster-impacted areas.

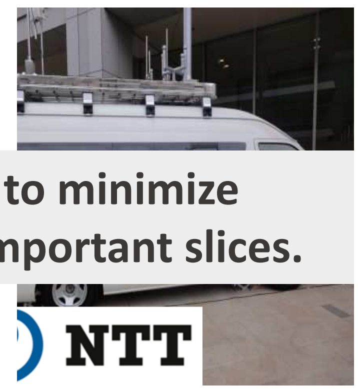
4 Power Distribution Trailer
Acts a sub-station for the recovery site – distributing commercial or generated power to the recovery and support trailers on a recovery site.

5 Emergency Communications Vehicle (*ECV)
Provides satellite-based VoIP, Ethernet and Wi-Fi service.

6 Satellite Cell On Light Truck (*COLT)
Provides 2G, 3G, and 4G service where normal cell service is unavailable.

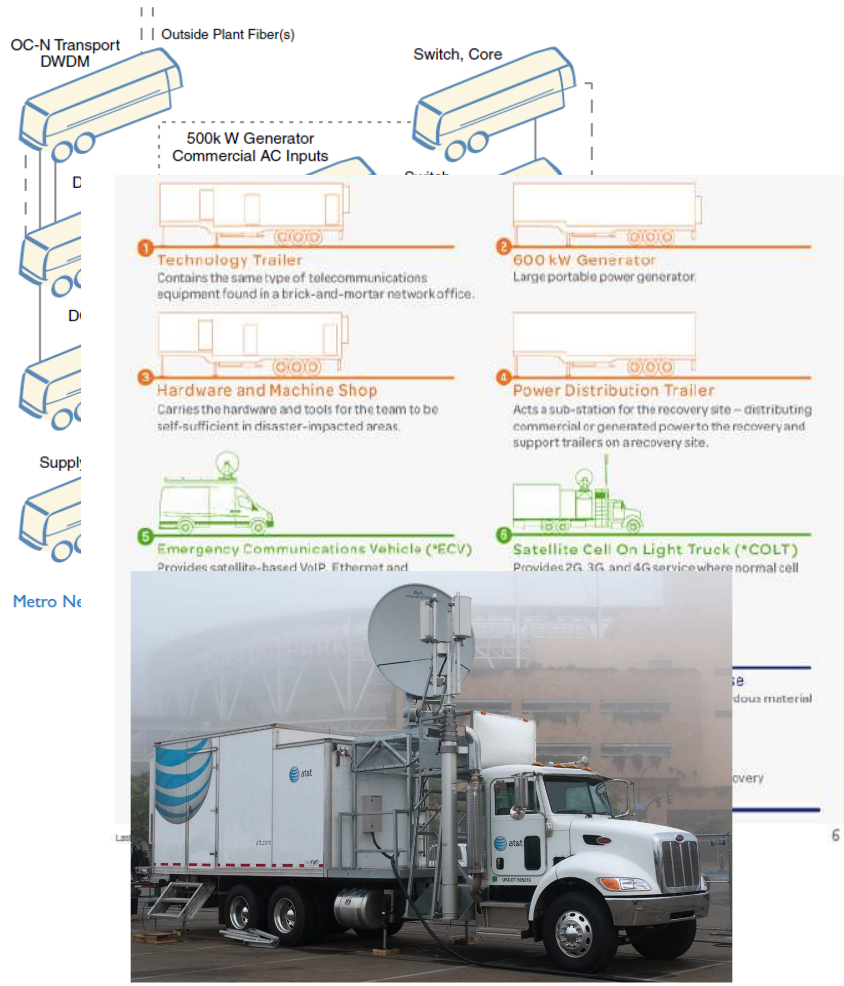
9 Command Trailer
Provides a central command location for the recovery site and allows communications to the GNOC.

Last updated on: Aug 2017 | © 2017 AT&T Intellectual Property. All rights reserved. AT&T and the AT&T logo are trademarks of AT&T Intellectual Property. 6

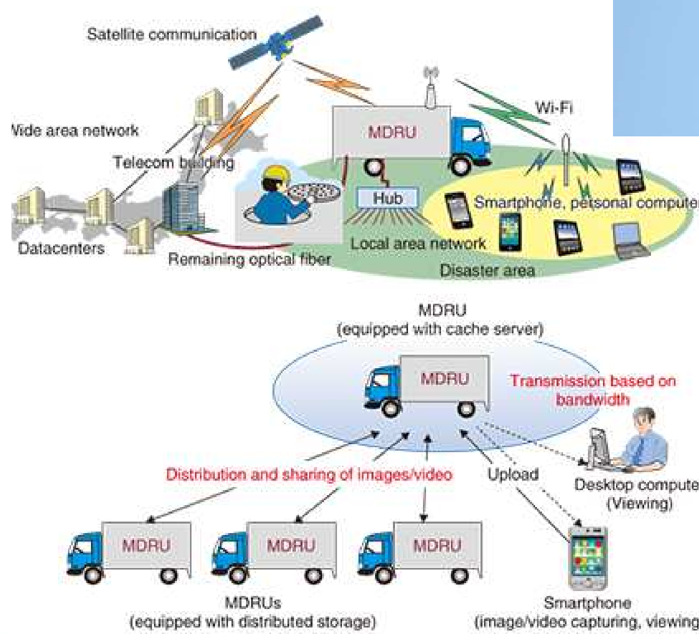


“Slice-aware” routing and deployment strategy to minimize downtime penalty and ensure fast restoration of important slices.

UC DAVIS
UNIVERSITY OF CALIFORNIA



FAA Approves Drone As 'Cell Phone Tower In The Sky' For Puerto Rico



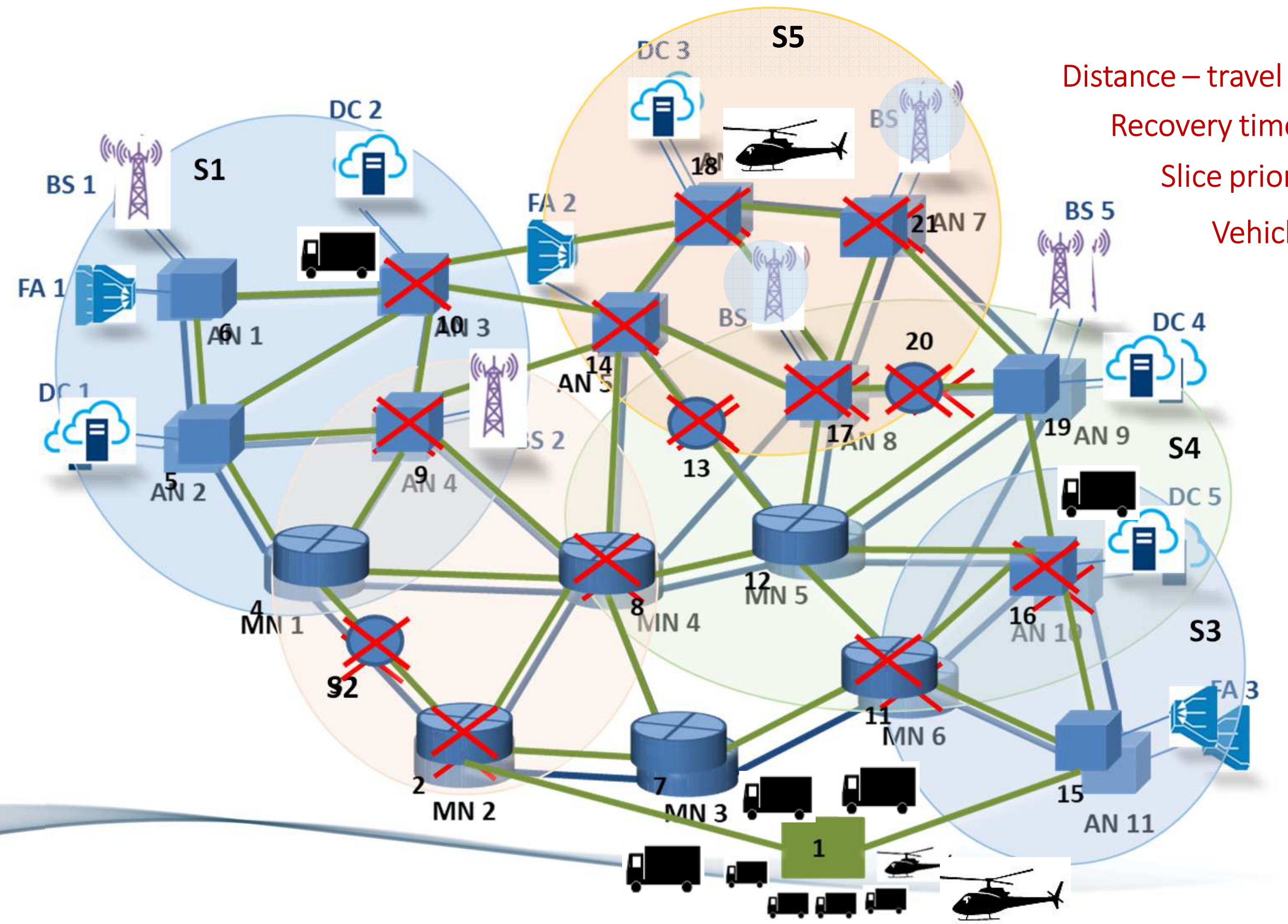
Slice-Aware Service Restoration

- Model the problem based on classical *vehicle routing problem*
- Recovery trucks provide both repair and *temporary relief/service* while repair work is going on (unlike general network recovery)
- Develop a “slice-aware” routing and deployment strategy for heterogeneous recovery trucks to heterogeneous failure sites

Minimize downtime *penalty* - fast restoration of important slices

UCDAVIS UNIVERSITY OF CALIFORNIA

Slice-Aware Service Restoration with Recovery Trucks



Distance – travel time

Recovery time

Slice priority

Vehicle type

Slice-Aware Service Restoration with Recovery Trucks

- Given: network topology, set of network slices, set of failed nodes, set of heterogeneous trucks
- Output
  - **Routes for recovery trucks**

$$min \sum_{s \in S} P^s$$

- Objective: Minimize service disruption penalty of slices
- Solution Approach
  - Mathematical model (MILP)

$$P^s = \sum_{r=1}^{\mathcal{T}} \sum_{i \in \bar{V}^{s,r}} \left(\alpha^s \cdot \beta_i^{s,r} \cdot Z_i^r\right), \quad \forall s \in S$$

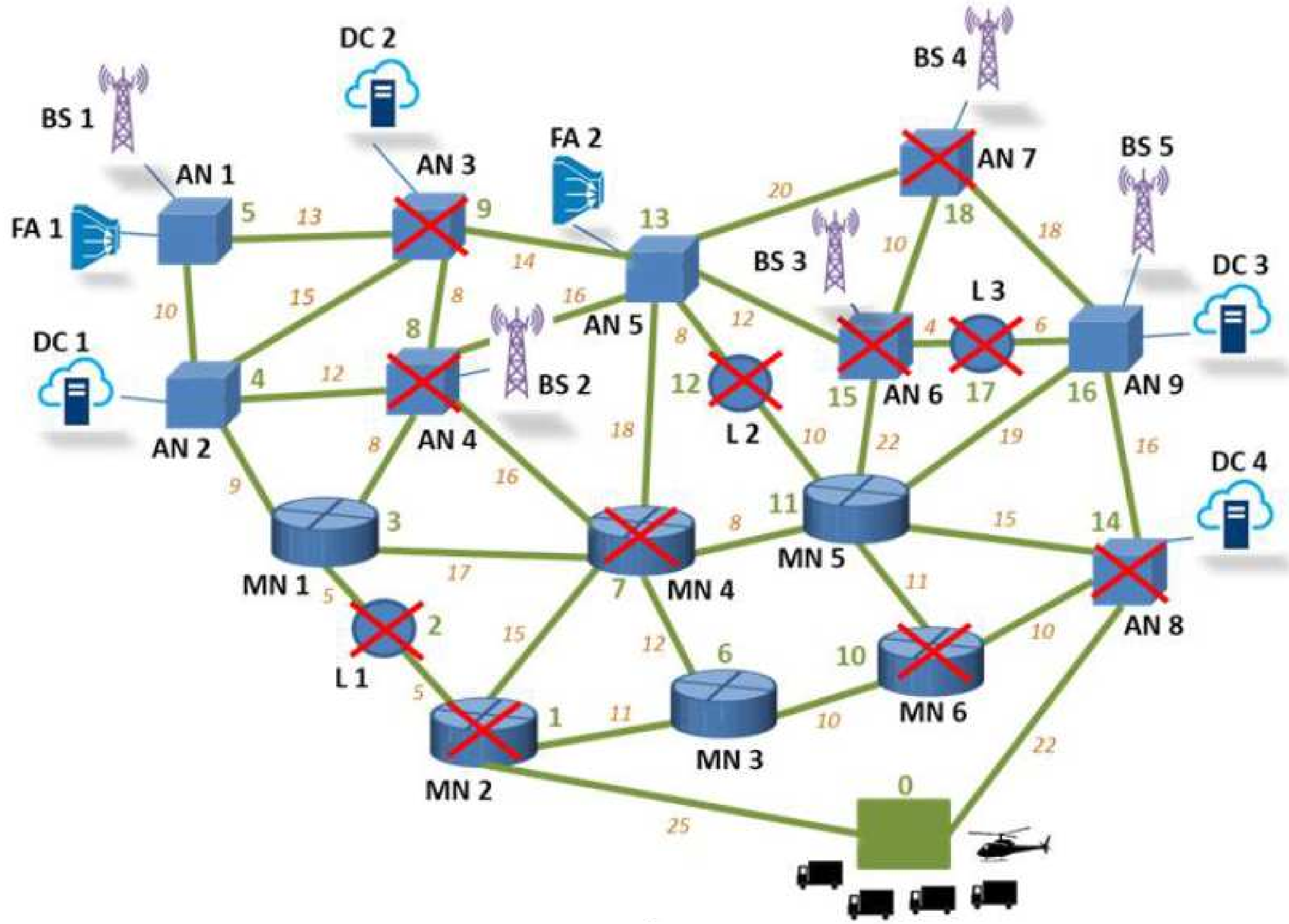
UC DAVIS
UNIVERSITY OF CALIFORNIA

Compared schemes

- Deployment schemes to be compared

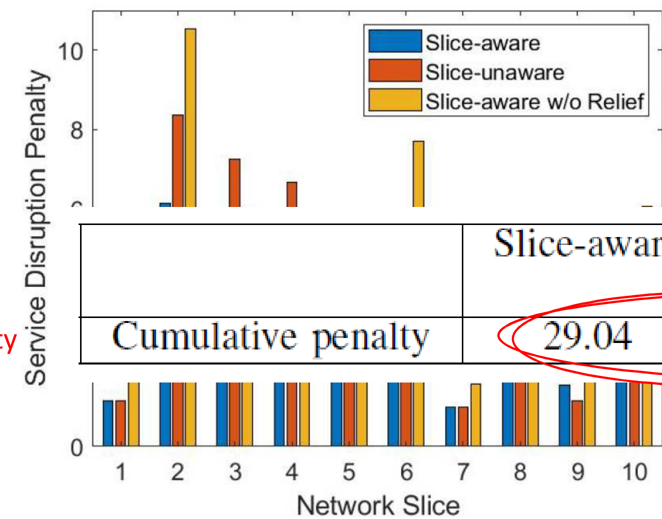
  - Slice-*aware* service restoration *with* temporary service (minimize penalty)
  - Slice-*unaware* service restoration *with* temporary service (minimize travel time)
  - Slice-*aware* service restoration *without* temporary service (repair only)

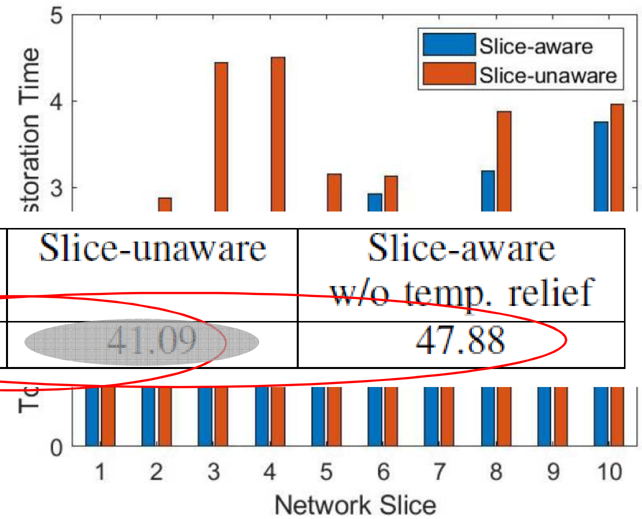
Simulation Setup



UCDAVIS
UNIVERSITY OF CALIFORNIA

Results





29% savings in penalty

	Slice-aware	Slice-unaware	Slice-aware w/o temp. relief
Cumulative penalty	29.04	41.09	47.88

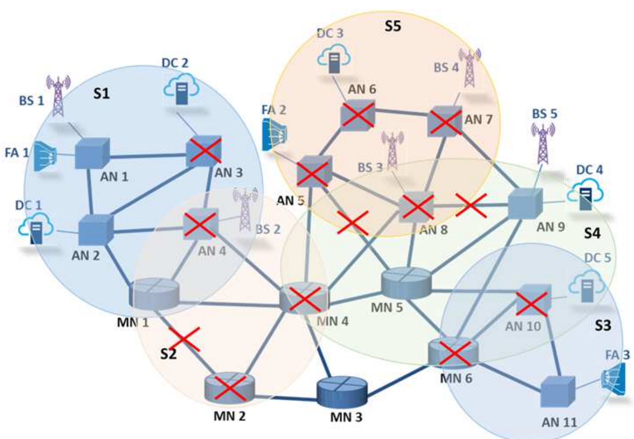
38% savings in penalty

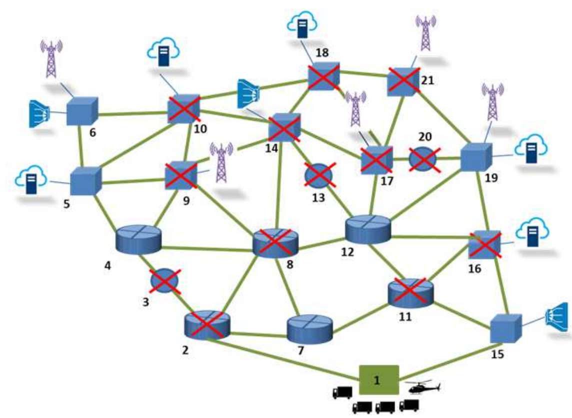
60% reduction in service disruption penalty

46% service-restoration time savings

Conclusion

- Our slice-aware service-restoration approach can achieve significant reduction in service-disruption penalty and savings in service-restoration time in a post-disaster optical metro-access networks





UCDAVIS
UNIVERSITY OF CALIFORNIA