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

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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
  - ...
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
Evolution of Metro-Access Networks

*Edge computing and SDN*
This transformation calls for trustworthy, high-availability, and sliceable next-generation metro-area networks (NG-MANs) that are resilient against disasters.
Types of Failure/breakdown

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

- 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.

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

- In the post-disaster phase, recovery trucks can provide both repair and temporary relief/service while repair work is going on (unlike general network recovery)

“Slice-aware” routing and deployment strategy to minimize downtime penalty and ensure fast restoration of important slices
Rapid network recovery with deployable recovery units

- In the post-disaster phase, recovery trucks can provide both repair and temporary relief/service while repair work is going on (unlike general network recovery).

- How to route the recovery trucks?
- Where to deploy the recovery trucks?
- When to deploy the recovery trucks and for how long?

“Slice-aware” routing and deployment strategy to minimize downtime penalty and ensure fast restoration of important slices.
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
Slice-Aware Service Restoration with Recovery Trucks
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

• Objective: Minimize service disruption penalty of slices

• Solution Approach
  • Mathematical model (MILP)

\[
\min \sum_{s \in S} P^s
\]

\[
P^s = \sum_{r=1}^{\tau} \sum_{i \in V^{s,r}} (\alpha^{s} \cdot \beta_{i}^{s,r} \cdot Z_{i}^{r}), \quad \forall s \in S
\]
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
Results

29% savings in penalty

60% reduction in service disruption penalty

38% savings in 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.