Slice-Aware Service Restoration for NG-MANs

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Motivation

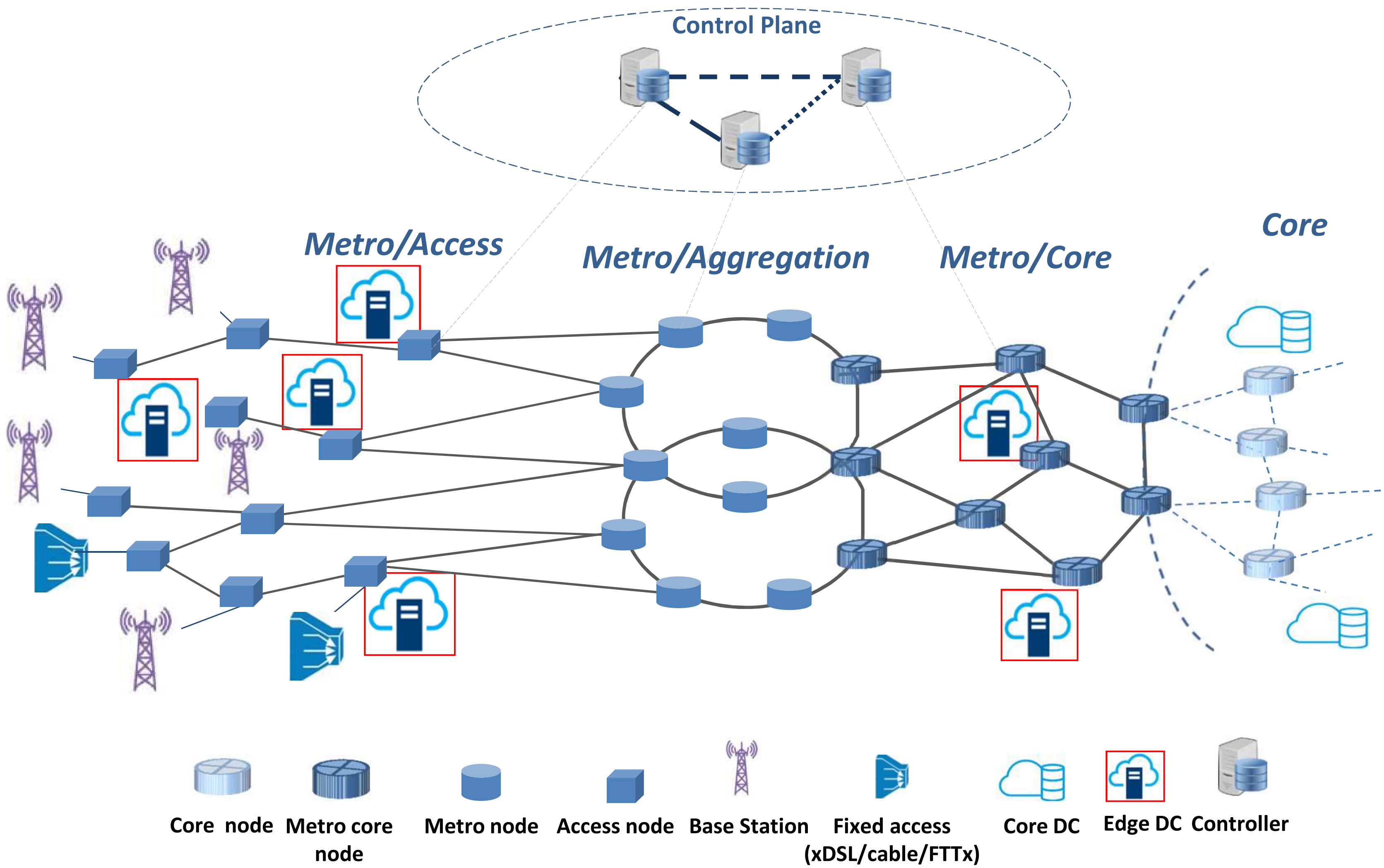
A new generation of optical metro networks is needed to turn the vision of "Smart Cities" into reality

- 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
  - …

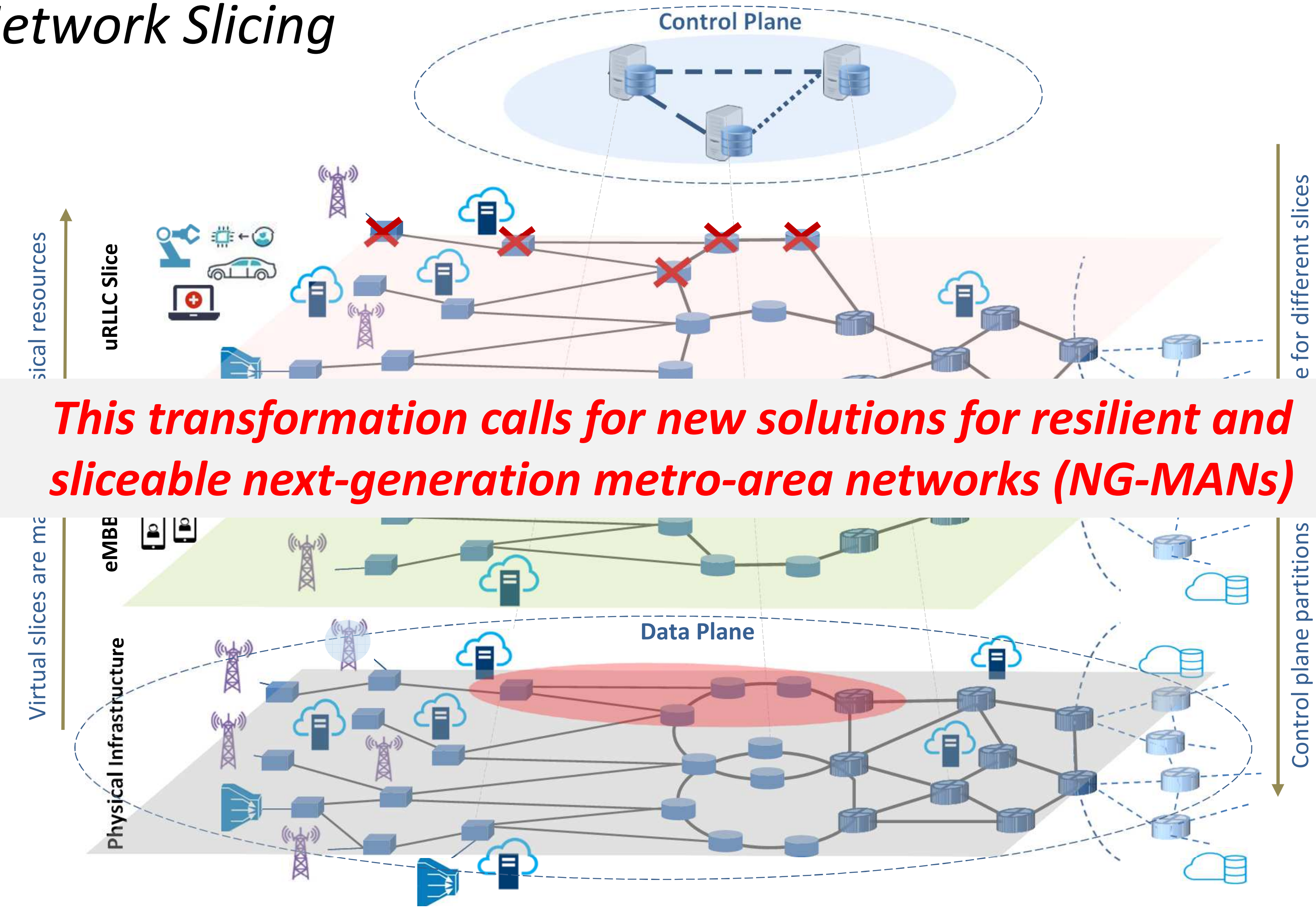
Evolution of Metro Access Networks (I)

Edge computing and SDN



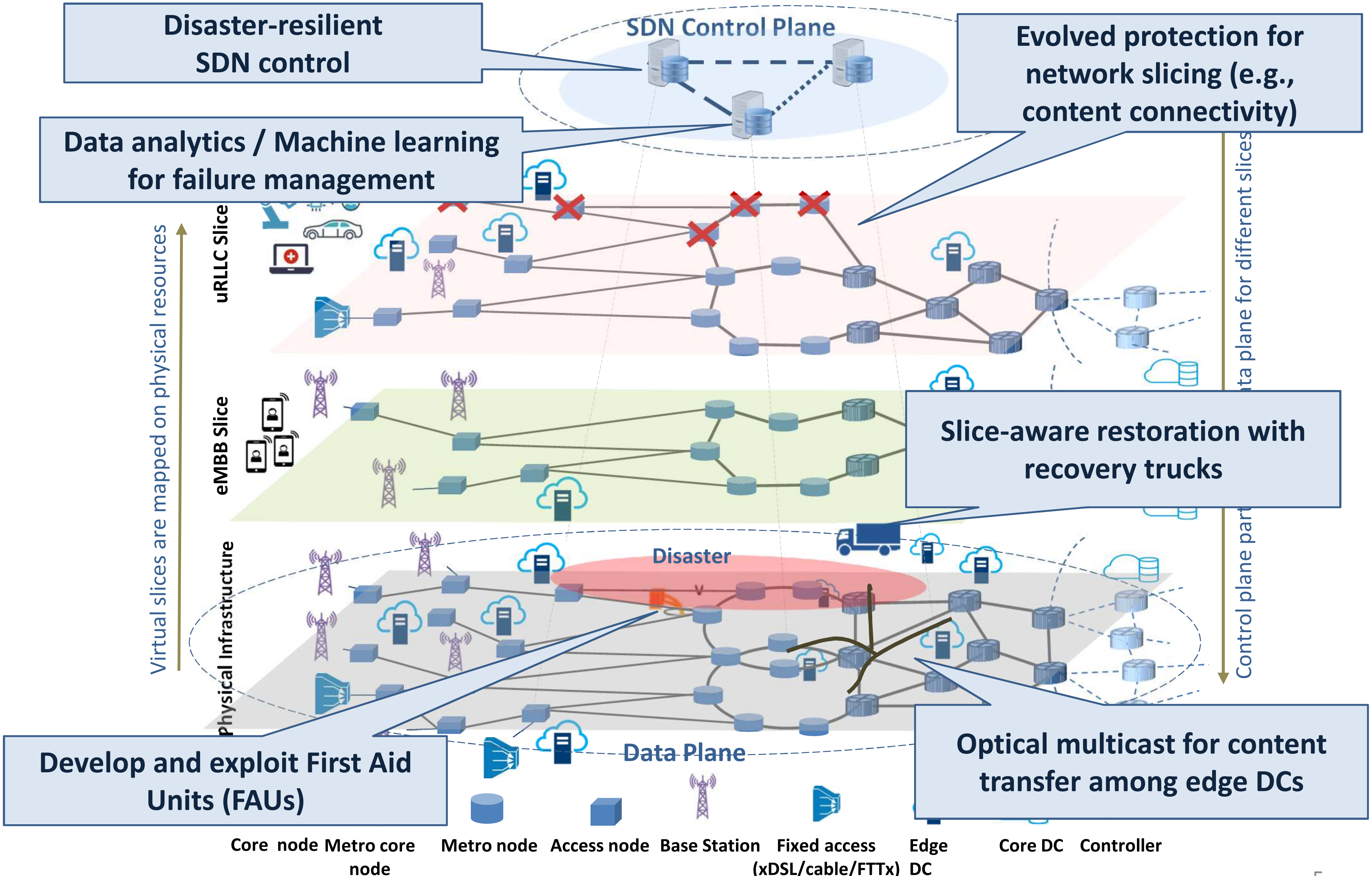
Evolution of Metro Access Networks (II)

Network Slicing



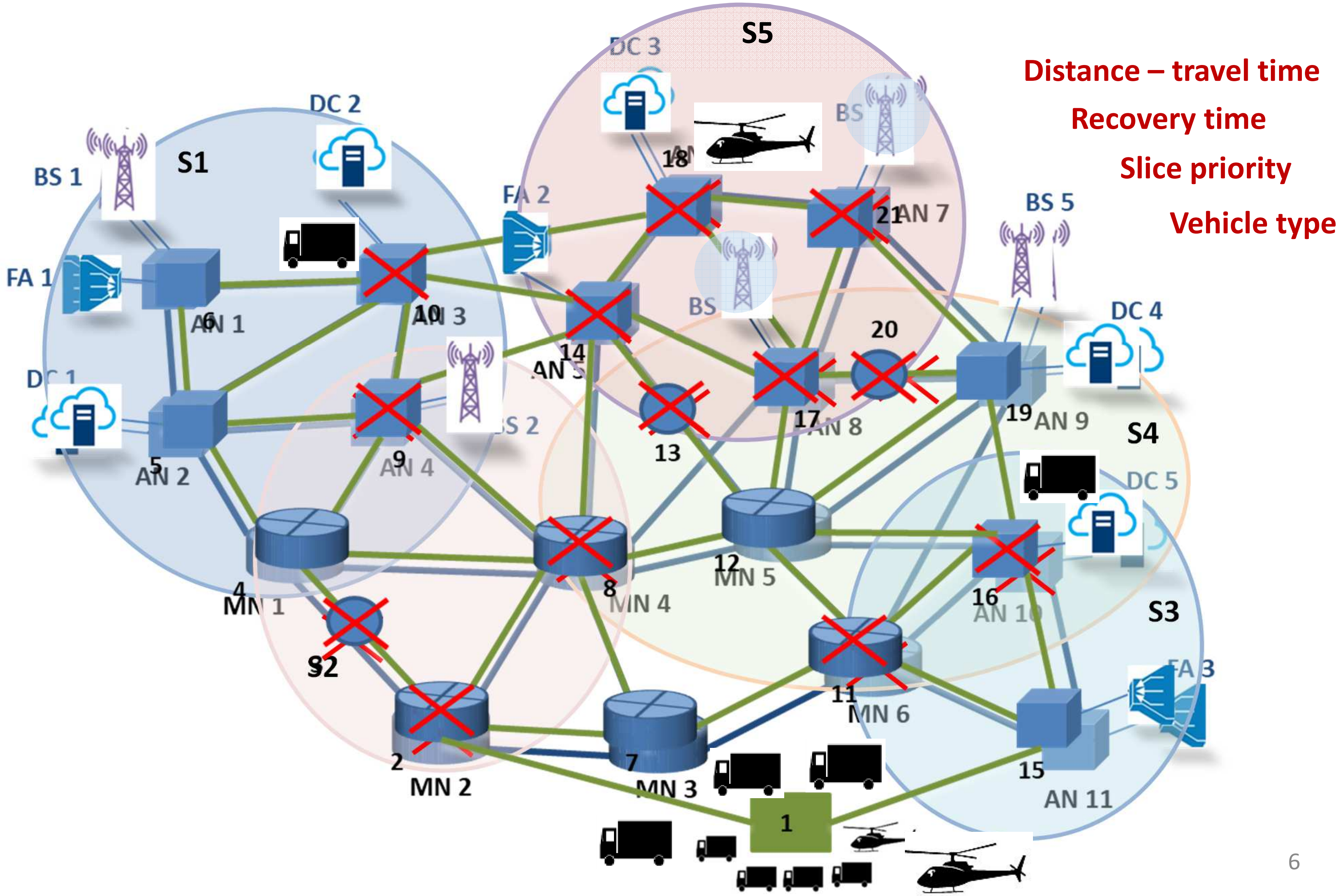
This transformation calls for new solutions for resilient and sliceable next-generation metro-area networks (NG-MANs)

Disaster affecting underlying NG-MAN



Disaster-resilient SDN control
SDN Control Plane
Evolved protection for network slicing (e.g., content connectivity)
Data analytics / Machine learning for failure management
uRLLC Slice
eMBB Slice
Physical Infrastructure
Virtual slices are mapped on physical resources
Control plane partitioning for different slices
Slice-aware restoration with recovery trucks
Disaster
Data Plane
Optical multicast for content transfer among edge DCs
Develop and exploit First Aid Units (FAUs)
Core node
Metro core node
Metro node
Access node
Base Station
Fixed access (xDSL/cable/FTTx)
Edge DC
Core DC
Controller

Slice-Aware Service Restoration with Recovery Trucks for NG-MANs



Alternatives for Recovery Trucks

- Battery power
  - *Drone Empowered Small Cellular Disaster Recovery Networks for Resilient Smart Cities*
  - *Post-disaster 4G/5G Network Rehabilitation using Drones: Solving Battery and Backhaul Issues*
  - *Multi-Drone Control and Network Self-Recovery for Flying Ad Hoc Networks*

- Road block
  - *Partial/incomplete knowledge of failures and the network state - fault tolerant restoration - we know how services are affected but not the network*
  - *Network kriging for failure localization*
  - *Network probing/monitoring - FAU*

Drones

- AT&T has designed an all-weather drone to keep its wireless network “flying” in a disaster.

- All-weather Flying COW drone designed by AT&T with help from manufacturers and first responders will be one of two types of drones that AT&T will offer for its Network Disaster Recovery (NDR) system.

- The drones come equipped with small cells and antennas. It’s compactness makes it easy to transport and deploy – can be moved quickly to accommodate rapidly changing network conditions in an emergency.

- Over time, drones are more integrated with the network so that as the network determines additional capacity or coverage is needed throughout the day, drones could be deployed from cell towers to these locations to provide that temporary extra capacity.
- When the network determines that capacity is no longer needed, the drones could return back to the cell towers to recharge and await their next mission as autonomously directed by the network itself.

- AT&T last year got FAA approval to fly its over-55-lb flying COWs in Puerto Rico to help customers and officials after Hurricane Marie devastated the country.
- The flying COWs provided data, voice, and text services to customers and recovery teams in Puerto Rico and carried dozens of gigabytes of data, and thousands of calls and texts.
- Because the drone can see through smoke and foliage, one use case for the drone is to maintain a network for firefighters to stay better connected out in a rural area, where they are fighting a fire.

- There are two major ways to practically implement Drone BSs (DBSs); tethered and untethered DBSs.
- A tethered DBS means that a drone is connected by a cable that provides power and/or backhauling.
  - Although it may sound uncanny for a drone to be tethered by a cable, this has many advantages such as a stable power source and hence unlimited flying time and ultra-high speed backhaul. All these advantages have encouraged well-known companies to test tethered DBSs, such as Facebook's "tether-Tenna", AT&T's "Flying Cell-On Wings (COWS)", and EE's, UK's largest cellular operator, "Air Masts".
  - Such a tethering feature also limits the operations of DBSs to taking off, hovering and landing only which in some cases is useful.

- On the other hand, untethered DBSs rely on the onboard battery for powering up the platform. Although untethered DBSs have limited flying time, they have fully controllable mobility in 3D space. Also, untethered DBS can adjust its placement based on users distribution.
  - In emergency zones, where the disaster causes total loss to the cellular infrastructure, the network has to be rapidly rehabilitated to facilitate and support the rescue operations of the first responders.
- The main technical challenges to face are the difficulty to charge and backhaul these DBSs -> use another drone to charge the DBSs on the fly. This special drone called Powering Drone (PD), has on its platform a large capacity battery which is used to charge the DBSs on the fly.
- For solving the backhaul issue -> use a tethered Backhaul Drone (tBD) which is powered and backhauled via cabling.

Optimization problem to minimize the energy consumption of the DBSs' network.

Network Kriging

- Network Kriging (NK) has been exploited as a mathematical framework to correlate linear parameters.
- In the field of optical networks, NK has been used to correlate physical-layer parameters with the aim of reducing the number of monitors or estimating QoT of lightpaths to be established.
- Lightpaths established specifically for monitoring purposes have been used as a way to enable fast restoration performed purely at the optical layer.
- Correlate framework based on NK for fault localization and leveraging information from lightpaths established for data communication in the network.

K. Christodoulopoulos, N. Sambo, E. Varvarigos, "Exploiting Network Kriging for Fault Localizatio," in proc. OFC, Anaheim, CA, 2016.