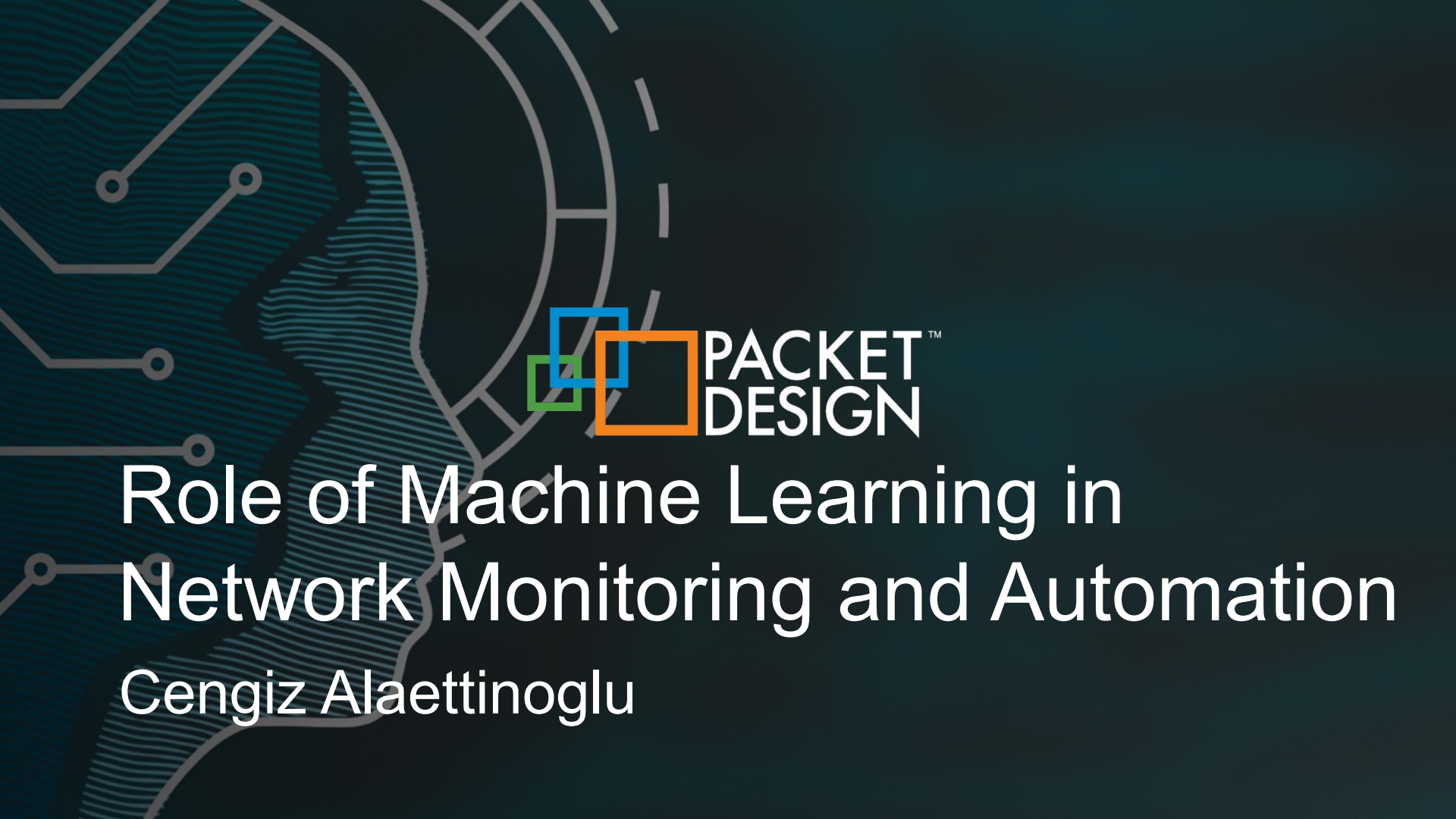
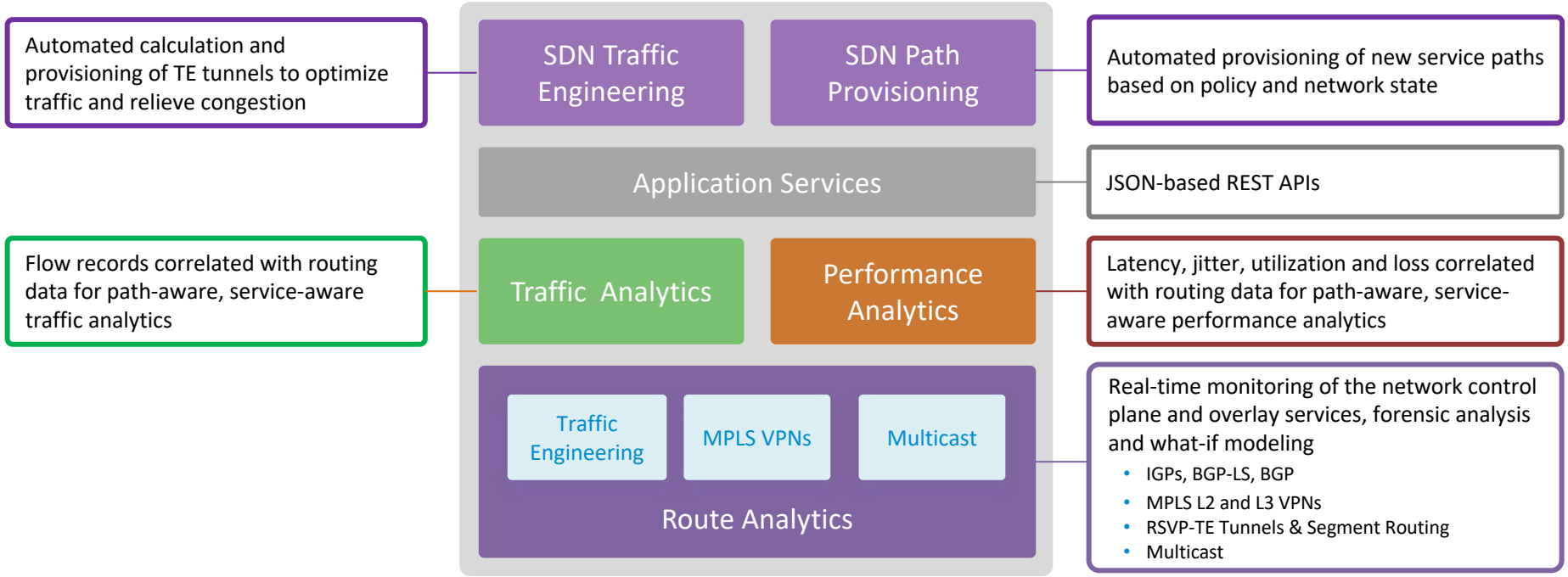


Role of Machine Learning in Network Monitoring and Automation

Cengiz Alaettinoglu

Machine-Learning Analytics Empowers Network Automation



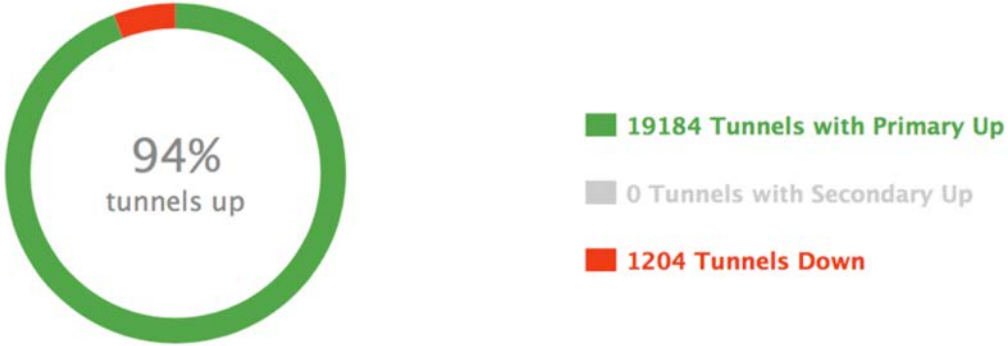
PACKET DESIGN

Network Automation Service Provider Trials

1. Provisioning assured bandwidth service paths
   - No RSVP or SR tunnels
2. Provisioning service paths
   - Various constraints
   - Segment routing (SR-TE)
3. Proactive service restoration
   - Link failure prediction
   - Critical services are rerouted before failure
4. On-demand traffic engineering
   - Multiple fiber cuts cause congestion and call drops
   - On-demand tunnels are created for alleviating congestion
5. On-demand multi-layer traffic engineering
   - Optimizing at the IP/MPLS layer alone still leaves some congestion
   - New optical paths are signaled and LAGs are reconfigured to add capacity to the IP/MPLS layer

PACKET DESIGN

Why Automate?



- Medium-size service provider has 6% of its RSVP-TE tunnels down
  - Due to race conditions after link failures
- 1200 down tunnels is too many for any operator to figure out the root cause
  - If these tunnels are for traffic engineering, can we really say we are successfully doing traffic engineering?
  - It is time for software/DevOps to manage the network?

PACKET DESIGN

Machine Learning

- Applications
  - Autonomous driving, natural language processing, classification, recommender systems, anomaly detection, prediction, clustering, self-customization, database mining, handwriting recognition, …
- Algorithms
  - From simple linear regression to deep neural networks
  - Neural networks are not new; however, access to large data sets and huge compute resources are now available and are responsible for recent attention
    - Very popular in 1980s; stagnated until recently
- It is not necessarily good at
  - Magic – many algorithms require supervision
  - Telling what it learned
  - It is not always accurate; Siri doesn't get me. I can't even read my own handwriting…

PACKET DESIGN

Machine Learning

- Trends
  - E.g. Detecting an optical interface card failure
- Normal vs abnormal – anomaly detection
  - BGP route hijacking
- Clustering
  - Subscriber behavior analysis
- Recommender Systems
  - Find similar past behaviors

1. Assured Bandwidth Service Paths

- Service provider wants to offer a portal where customers can request assured bandwidth service paths
- Can the network assure the service?
  - Cannot disrupt current services; i.e. it cannot cause congestion
- Shortest paths only
  - No existing tunnels, nor plans to introduce tunnels

PACKET DESIGN

Path Computation

- Computing the shortest path is easy
- Checking the interface utilizations along the shortest path is not sufficient
  - What happens tonight when the traffic peaks?
    - Or over the course of the week?
  - What happens when a link fails?

PACKET DESIGN

Role of Machine Learning

- With nothing learned, all requests are accepted
  - Very high probability of causing congestion for many requests
- With just the real-time network demands and paths learned
  - Very low probability of causing congestion in short term
  - High probability of causing congestion later
- With week-long network demands and paths are learned
  - Very low probability of causing congestion now or later
- Why stop at a week?
  - Traffic has both diurnal and weekly patterns
  - Networks evolve – new routers, new applications; better to forget at some point
- Why not use neural networks here?

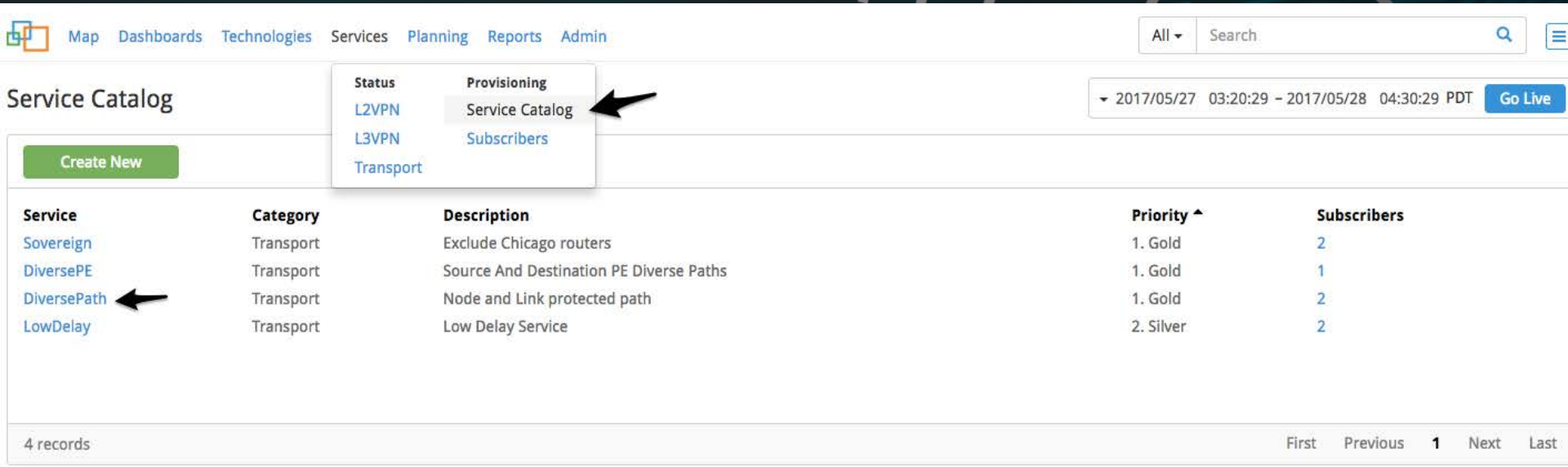
PACKET DESIGN

2. Intent Based Service Paths

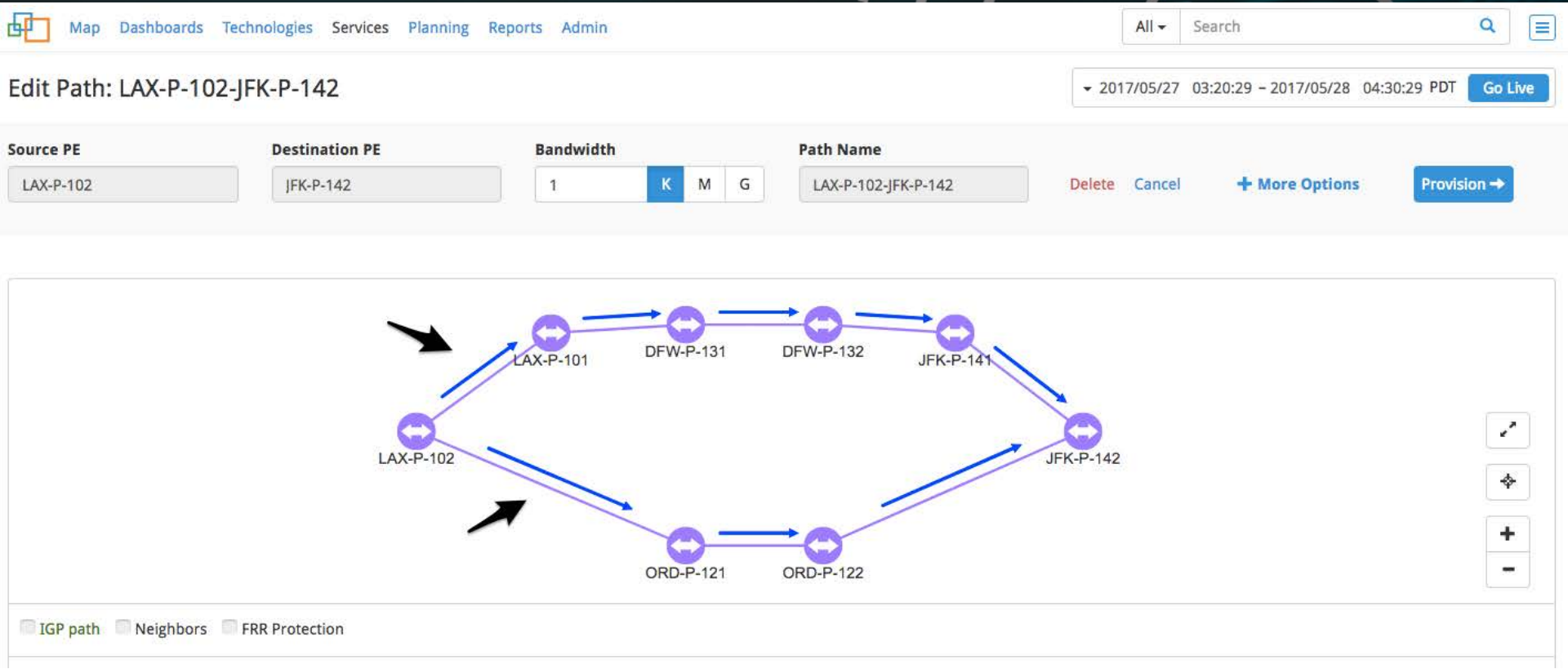
- Intent: provide subscribers paths with various service requirements
  - Low-delay paths for financial enterprises
  - Bandwidth-guaranteed paths for fat flows for broadcasters
  - Diverse paths for full redundancy
  - Geo-constrained paths for sensitive data
  - “Pay what you use” on-demand, on-the-fly paths
- Subscribers
  - Cola, Pepsi, Red Bull,…
- Paths
  - LA to NY low-delay path for Cola
  - Path may be non-shortest using RSVP-TE and SR-TE

PACKET DESIGN

Service Creation



Diverse Path Creation Example

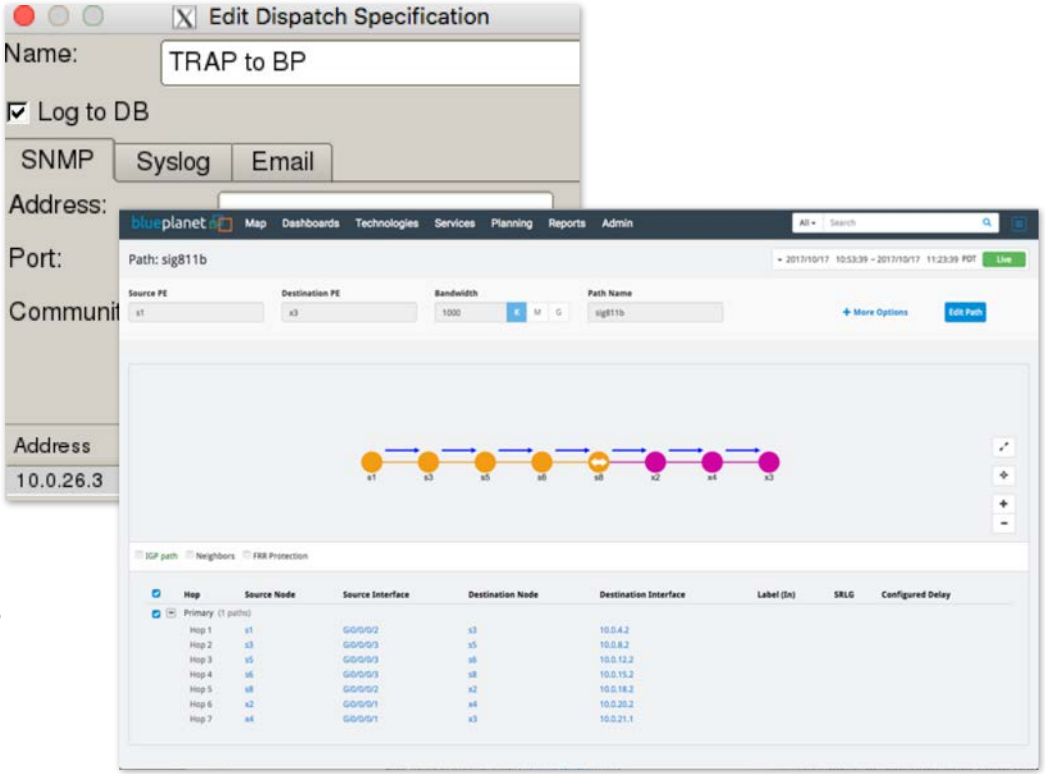


3. Proactive Service Restoration

- Optical interface cards generate heat and eventually fail
- The CRC error rate increases as the card degrades
  - This behavior can be learned
- Service provider wants to proactively reroute critical services away from degrading equipment

PACKET DESIGN

Self-Driving Network Trial



- Performance Explorer detects link errors
  - Orchestrator is notified
- Orchestrator requests new paths for critical services
  - New policy: “Exclude the problem link”
- Path Provisioning application re-computes new paths avoiding the problem links
- Orchestrator reconfigures routers

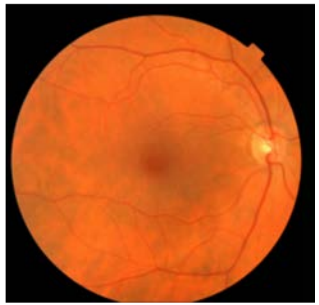
PACKET DESIGN

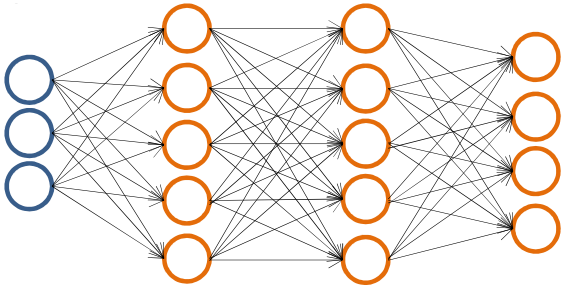
Role of Machine Learning

- CRC error rates are baselined for anomaly detection
  - Need to be careful as there are no CRC errors when idle
- The growth in CRC error rate can be detected
  - Normalization
- Why not use a neural network here?
  - Really good match for the problem

PACKET DESIGN

Neural Networks



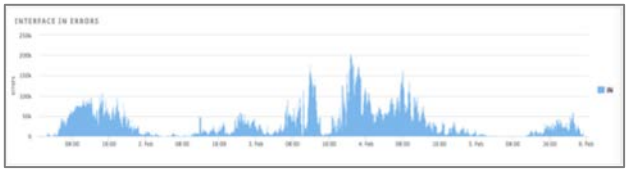


- Input layer
  - The pixel values of the image
- Hidden layers
- Output layer
  - Probability of a heart attack
  - Age of the person
  - BMI
  - Smoker or not
  - Whether has high blood pressure

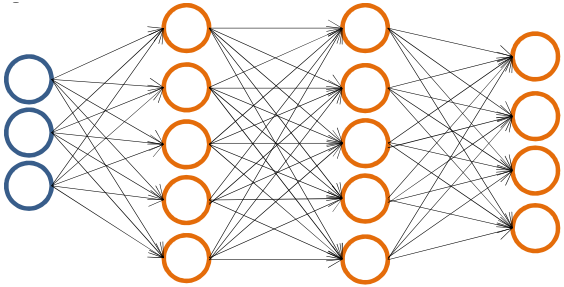
- Training data set: 300,000 retinal images and expected outputs
  - Coefficients are determined by best-matching the training set
- Test data set: 13,600 retinal images and expected outputs
  - 70% accurately predicted
  - 72% is the medical accuracy rate with a blood test

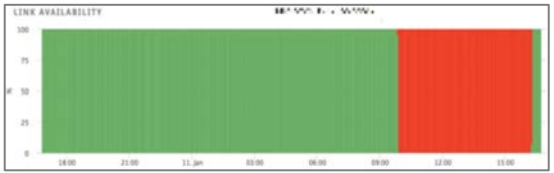
PACKET DESIGN

Optical Interface Failure



CRC Errors





Link Availability

- Input layer: 5-minute CRC error rate for the last 30 days
- Output layer: probability of a failure in next 1 hour, 1 day, 1 week, 1 month
- Hidden layers: start with 2 layers and check the results if more needed
- Training data set
- Test data set

PACKET DESIGN

1980s All Over Again

- Algorithm – yes
- Access to compute power – yes
- Large data sets – not yet
  - In the dataset:
    - 48 link failures over the week
    - 12 links
    - Only one link stayed down for more than one hour
    - 9 interfaces with significant CRC errors, including this link

4. On-demand Traffic Engineering

- Congestion caused by fiber cuts
  - Normally the network is run uncongested
- Traditional optimization algorithms are too slow
  - NP-Complete
  - Take hours to compute
- Packet Design congestion-avoidance algorithm runs in seconds
  - Polynomial time

PACKET DESIGN

SOLUTIONS PRODUCTS ABOUT RESOURCES

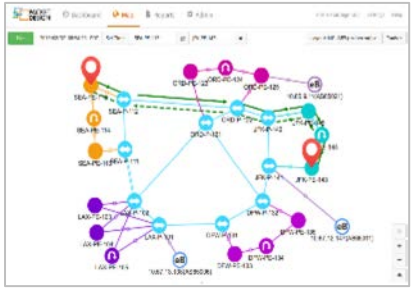
XL Axiata Deploys Packet Design Explorer SDN Traffic Engineering Application to Assure Network Services

October 10, 2017

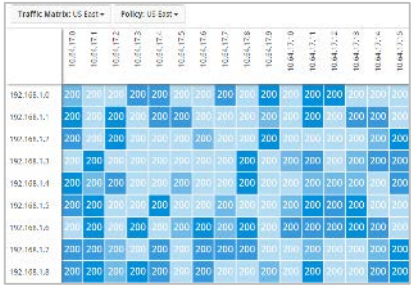
Wireless service provider optimizing its network using SDN analytics and automation technology

AUSTIN, Texas – October 10, 2017 – XL Axiata, one of Indonesia's leading telecommunications service providers covering 90 percent of the country's population, has deployed Packet Design technologies to ensure optimum service delivery over its IP/MPLS mobile and core networks. XL Axiata chose the Packet Design Explorer Suite, including its Carrier SDN analytics and automation capabilities, to improve troubleshooting, automate traffic engineering to avoid link congestion, and mitigate risk as it expands and rolls out new services.

SDN Traffic Engineering Application



Topologies
Real-time physical or virtual
Link delay/loss/jitter
Baselines
Anomalies
Alerts



Traffic Matrices
Service aware
Peak or current traffic levels
Full-mesh or tactical

Policies

Network Policies
Under-/over-provision
Optimization criteria
Resiliency requirements
Etc.

TE Recommendations
Add, delete, merge, split tunnels

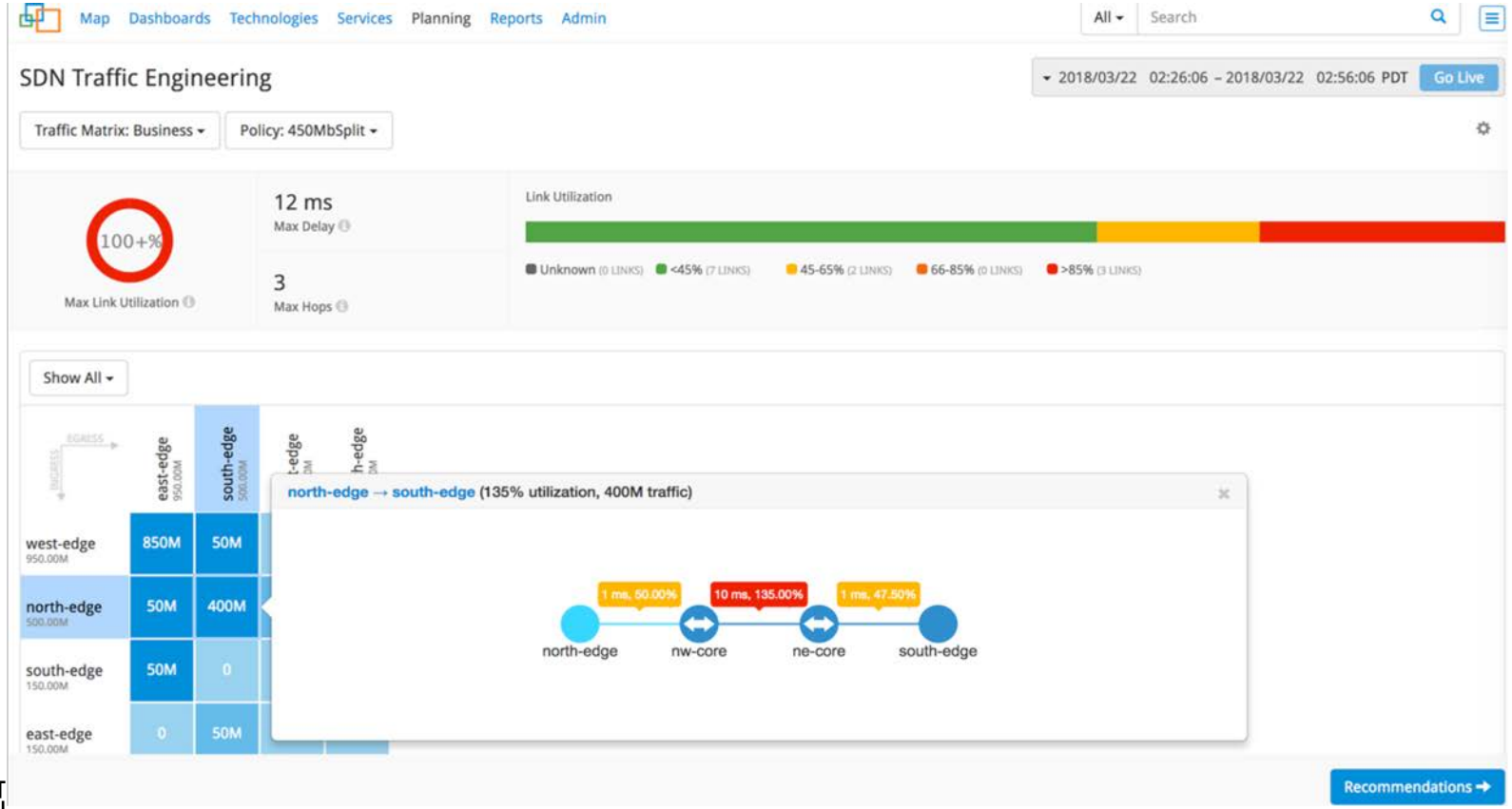
Programming
SDN controllers
Orchestrators

Closed loop: analytics & policy-based recommendations, provisioning, monitoring

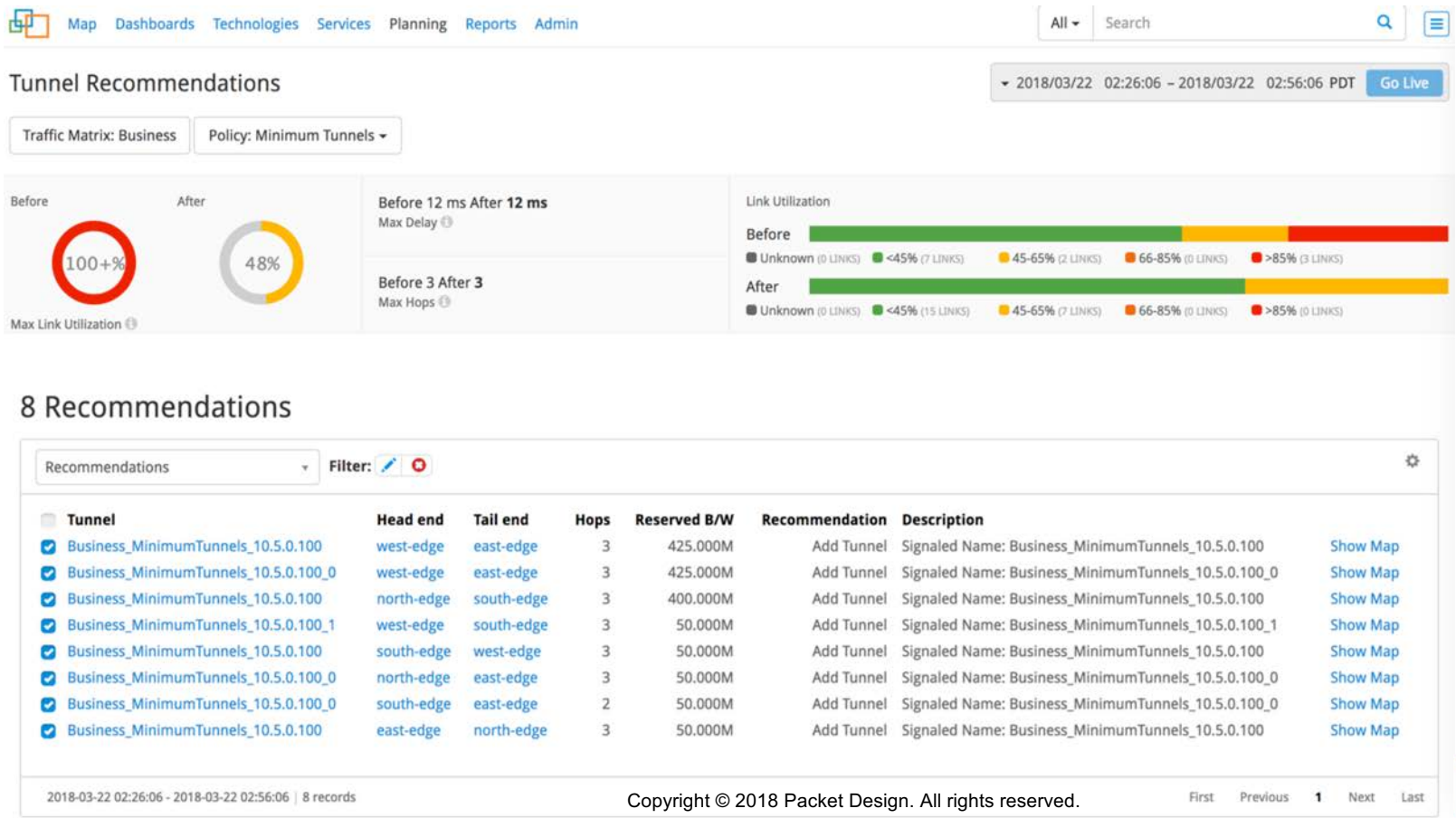
PHYSICAL & VIRTUAL ROUTERS, SWITCHES & NETWORK FUNCTIONS

PACKET DESIGN

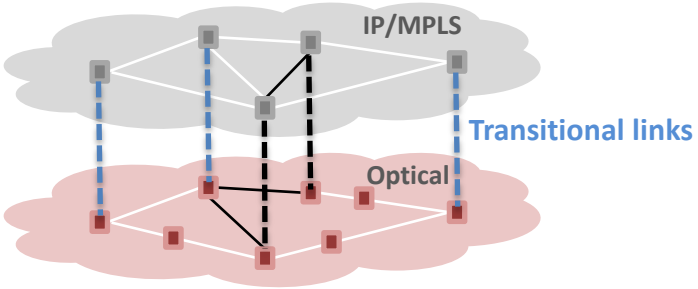
Traffic Demands and Network Conditions



TE Saves 60% Capacity



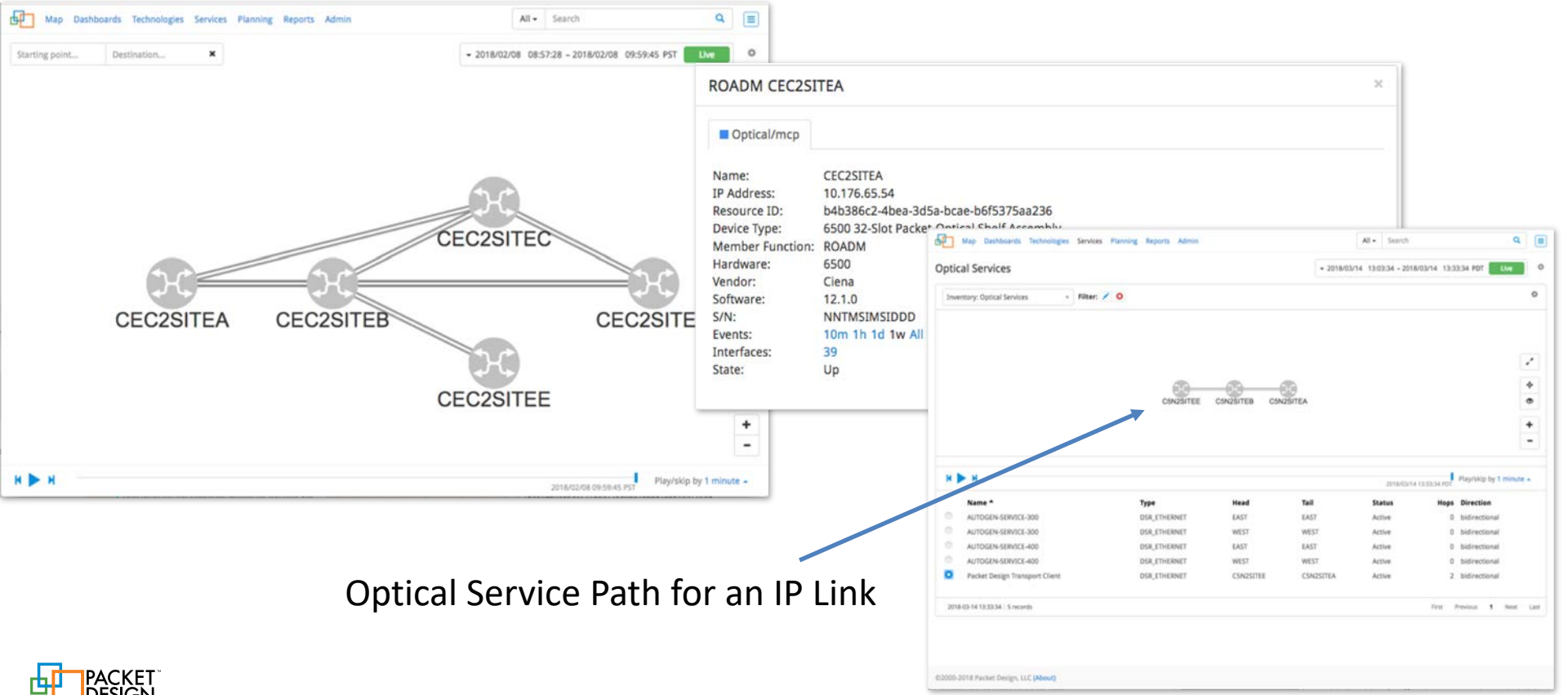
5. On-Demand Multi-Layer Traffic Engineering



- Traffic engineering at the IP/MPLS layer
  - IP rerouting is faster than optical – in sub-seconds
  - Optimization algorithm must work in seconds also, not hours
- Optimizing at the IP/MPLS layer alone may not always succeed
  - Especially with fiber cuts
- Optical network is slow but can help
  - Capacity of some optical paths can be adjusted
    - Flex-Ethernet, liquid-spectrum, partial restoration at the optical layer
  - New optical transport paths can be signaled

PACKET DESIGN

IP/MPLS and Optical Topology Correlation



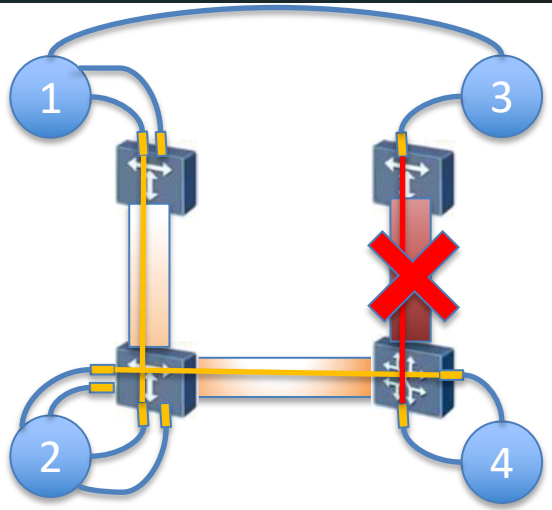
Optical Service Path for an IP Link

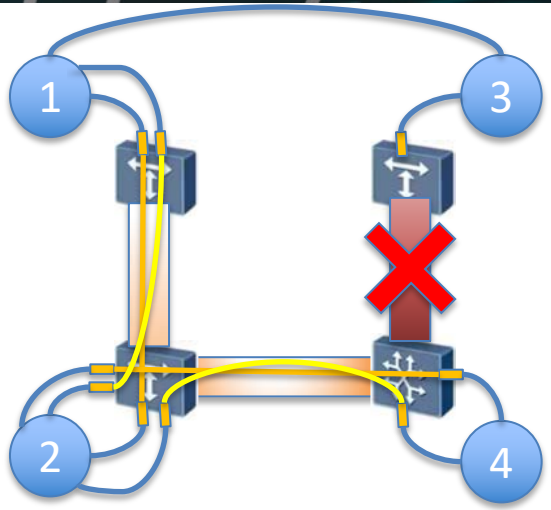
Multi-Layer Traffic Engineering

- It is possible to re-engineer the IP links/ports and optical service paths
  - However, optical rerouting is destructive and takes ~5 minutes
- Re-engineer unused ports
  - Ports of the failed links are unused
  - Look for under-utilized link aggregation groups (LAGs)
- Create new IP links between these ports
  - Only where capacity is needed
  - Coordinate IP and optical network changes to avoid packet drops

PACKET DESIGN

Multi-Layer Traffic Engineering





- Role of IP layer
  - Identify the new layer 3 path
  - Identify how much capacity is needed and where
- Role of optical layer
  - Repurpose an optical port on ROADM
  - Signal two new paths

- Role of orchestrator
  - Coordinate the two pieces
  - Add new IP links to the LAGs

PACKET DESIGN

Role of Machine Learning

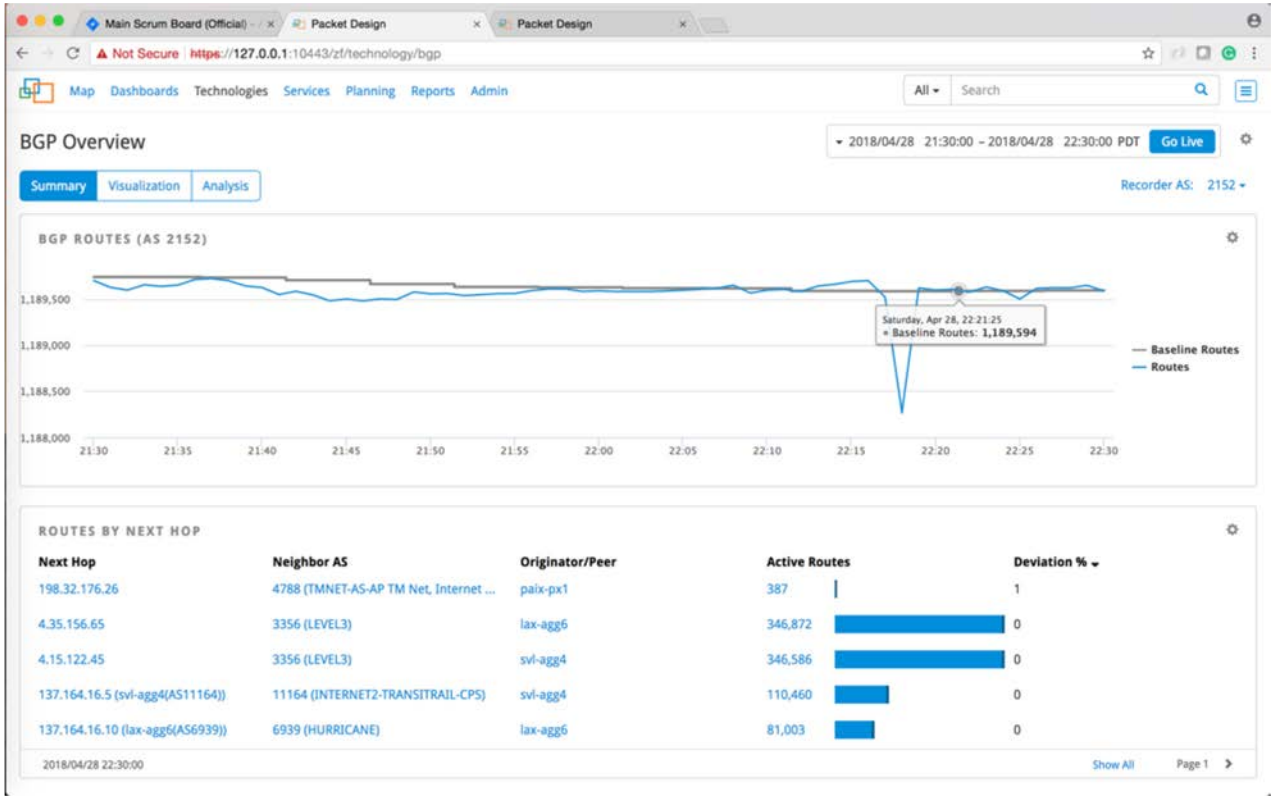
- Many traffic patterns can be learned
  - Traffic matrices with neural networks
    - http://ieeexplore.ieee.org/document/7849067/
    - https://arxiv.org/pdf/1711.02833.pdf
  - DDoS
  - Traffic anomaly detection
  - Peering traffic optimization
  - …

PACKET DESIGN

BGP Route Hijacking

- Happens too often
  - BGP makes you (in)famous
- Until we can protect the routing system, we need automatic detection and fast restoration
- Baselining BGP routes helps

BGP Route Baselines



- Baselines
  - Origin AS
  - Neighbor AS
  - 2nd hop AS
  - BGP next hop
- Alerting

Concluding Remarks

- Network analytics empower many service provider use cases
- Network trends and anomalies can be machine learned; some failures can be predicted
- Self-driving network can reroute around congestion and move critical services away from failing equipment
- Correlating IP and optical layers provides a more holistic self-driving network

PACKET DESIGN