Sprint

On Quantitative Network Efficiency

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Why?

For a service provider, or any enterprise with substantial network infrastructure, achieving a high network efficiency is often a noble goal or even an important KPI. But

- What kind of efficiency we're talking about? Is it capacity (capex)? Is it operation (opex)? Or is it business (e.g., service agility)? Or is it all of them?
- Are these different goals compatible to each other or in conflict?
- Does it worth the trouble/cost to achieve what?
- What are the roles of technology advancement in different network layers play into which of the above goals?

Do we have these concepts clearly defined and **quantified**?

Numbers may not tell the whole story, but they tell the truth.

Network Efficiency: Classified

- Capacity Efficiency ($E\downarrow cap$):
  - Measures how the network is designed, built and used: **capex, topology, and utilization**
  - Affects bottom line, run by Engineering
- Operation Efficiency ($E\downarrow ops$):
  - Measures how the network is operated and performing: **opex (staffing and tools), events**
  - Affects bottom line, run by Operations
- Service Efficiency ($E\downarrow srv$):
  - Measures how the network is put to use: **speed to market, order fulfillment, development costs**
  - Affects top line, run by Development

Network Efficiency: Defined

- Capacity, Operation and Service Efficiencies could be in conflict or in competition if pursued disjointedly.
- They need to work together to meet the business goals.

- Network Efficiency *can* be defined as

$$E_{nwk} = (x * E_{cap} + y * E_{ops}) * E_{srv}$$

where *{x, y}* are weight factors representing business needs and may be a function of time to reflect changing business environment.

Management should set clear objectives and priorities by defining *{x, y}* which drives resource allocation.

Service Efficiency

- **Definition:**

$$E_{srv} = (T_{pro} - T_{dev}) / T_{pro} * T_{cst} / (T_{cst} + T_{ord}) * S_{cap} / (S_{cap} + S_{dev})$$

where T_{pro} is effective product earning life cycle, T_{dev} is product development time, T_{cst} is customer life cycle, T_{ord} is order fulfillment time, S_{dev} is development cost (lab, staff, etc.), and S_{cap} is capex.

  - E_{srv} reveals the efficiency and effectiveness of network organizations.
  - Indecision, lack of vision, and slow to react to new markets and products all contribute to a lower service efficiency.

- **Opportunity Cost**

  Lost revenue $\$_{rev} \propto (1 - E_{srv}) \propto T_{dev}$

  - E_{srv} represents the hidden opportunity cost often neglected.

Operation Efficiency

- **Definition:**

$$E_{ops} = S_{cap} / (S_{cap} + a * S_{ops} + b * S_{pnt}) * (1 - N_{err} / N_{m})$$

where S_{ops} is network support opex, S_{pnt} is penalty cost due to network events, S_{cap} is capex, N_{err} is network events due to human error, and N_{m} is all maintenance events.

  - S_{pnt} includes credits to customers, fines, repair cost, etc.

- **Operation Cost:**

$$S_{ops} = S_{ppl} + S_{tool}$$

  - One may prefer tools than staff, but a highly trained staff can use the tools more effectively and productively.
  - A very low S_{ops} may trigger a higher S_{pnt} .
  - The modern role of dev ops.

Capacity Efficiency

- **Definition:**

$$E_{cap} = U_{nrm} = U_{pkf} = S_{edge} / (S_{core} + S_{edge})$$

$$= C_{wk} / (C_{wk} + C_{prt}) * (1 - N_{cap} / N)$$

where U_{nrm} is average network utilization during normal conditions, U_{pkf} is network peak utilization during failure, C_{wk} is working capacity, and C_{prt} is protect capacity, S_{edge} is edge capex, S_{core} is core capex, N_{cap} is network events caused by lack of capacity, and N is all network events.

- Multiple angles to evaluate, though not equivalent.
- Optical, OTN, IP and Control Plane each has its own impact.

Capacity Efficiency: General Rules

- Business goals and SLA contracts define the desired traffic behavior during failure:
  - Classes of traffic that require protection and prioritization
  - Maximum failover timescale
  - QoS policy
  - Latency constraints
  - Single or multi-failure protection
- Network topology optimization considerations
  - Traffic patterns that are function of time
  - Fiber plant and diversity requirements
- Technology selection and capacity deployment cycle

Capacity Efficiency Impact by Layer

- **Optical: Layer 0**
  - Wavelength-based, used to be lowest cost but not anymore.
  - Slow reaction during failure, no statistical mux, require more idle capacity.
  - Not ideal for protection, can perform restoration with certain value.
- **OTN: Layer 1**
  - Sub-wavelength-based, requires OEO.
  - Fast reaction during failure, still no statistical mux, requires idle capacity.
  - Suitable for protection in certain cases.
- **Ethernet/IP/MPLS&TE: Layer 2/3/2.5**
  - Packet-based, requires OEO.
  - Fast reaction during failure, highest statistical mux gain.
  - Abundant and mature traffic engineering (TE) capabilities, but local.

Need to avoid race conditions!

Capacity Efficiency: An Ultimate Solution

Optimally filled, statistically muxed, frame-switched, true packet-optical transport

- **Use buffer to optimally fill each OTN frame;**
- **Mark each frame with TE bits;**
- **Switch and mux OTN frames in waves, transport data frames to destination based on TE bits instruction.**
- **Empty frames are always the first to be dropped.**

Treat OTN frames like packets, implement mature Layer 3 TE technologies at Layer 1, make a true packet-optical transport network, not the Packet-over-OTN (POO ≈ POS) as today.

Who will / can bring this technology to market first?

Network Efficiency: Interaction

$$E_{nwk} = (x * E_{cap} + y * E_{ops}) * E_{srv}$$

$$E_{cap} = C_{wk} / (C_{wk} + C_{prt}) * (1 - N_{cap} / N)$$

$$E_{ops} = S_{cap} / (S_{cap} + a * S_{ops} + b * S_{pnt}) * (1 - N_{err} / N_{lm})$$

$$E_{srv} = (T_{pro} - T_{dev}) / T_{pro} * T_{cst} / (T_{cst} + T_{ord}) * S_{cap} / (S_{cap} + S_{dev})$$

- Mathematics vs. Business
- The human factor

Network Efficiency: Control Plane

- Control plane ?= IP / MPLS / TE / TP + PCE / OF / SDN

  = Coordinated Local & Global View/Control/Optimization in SW

  *** Operator warning: A messy control plane = Global chaos**

- Automation = Higher efficiency
  - $E{\downarrow}srv$: Technology certification, service creation, concept testing …
  - $E{\downarrow}ops$: Traffic engineering, self-healing, …
  - $E{\downarrow}cap$: Capacity optimization/creation, dynamic topology update, …
- Intelligence ?= Higher efficiency
  - $E{\downarrow}srv$: …
  - $E{\downarrow}ops$: …
  - $E{\downarrow}cap$: …

  Use your imagination and ingenuity to dream, invent, and create.

Thank You

Questions?