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Network Reliability Advances

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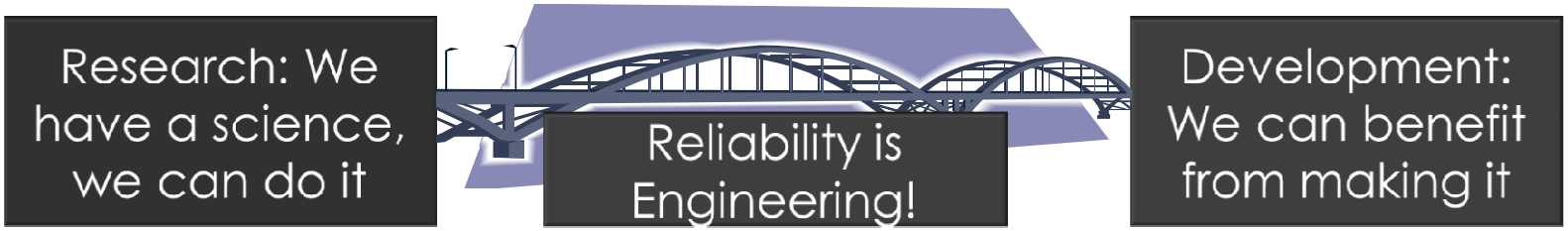
But first: a contrasting word about reliability

- The IEEE has 38 Technical Societies, with the Reliability Society being one of the first ever created.
- Most are centered around a technology or industry. Few are centered around a skill set or goal, maybe a fourth or less.
- What is reliability really about? Sure, making things more reliable. But what does that really mean?



Outline

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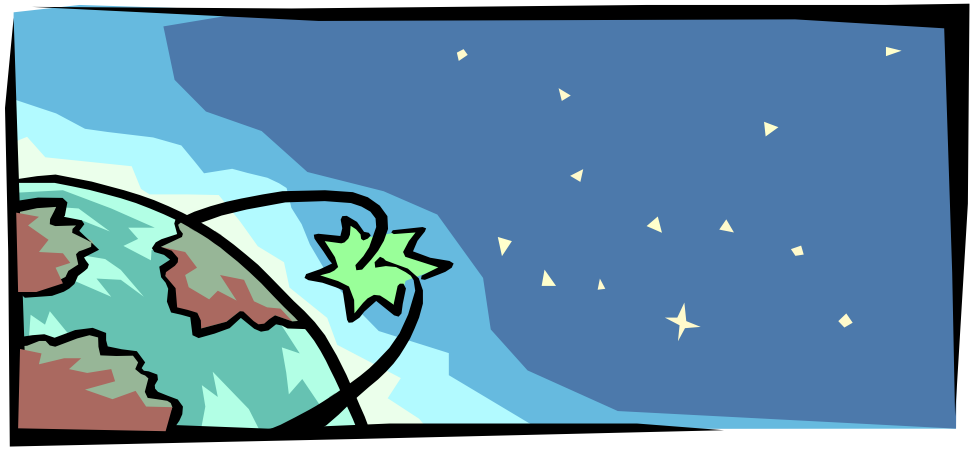
- Where the research focuses in IT-Telecom vs. OR vs. others?
- What are the practical problems and how do we solve them?
- Where is the real frontier of value? – sharing perspectives, information, use and test cases, common tools perhaps?



Indications of Disconnect

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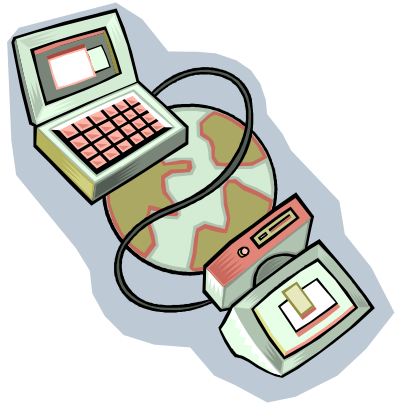
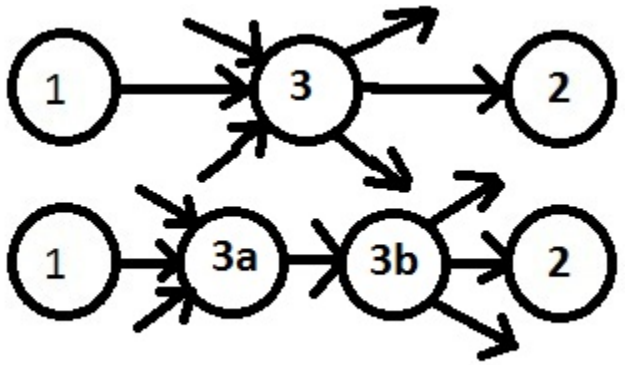
- Power systems largely ignore work done by others who are decades ahead.
- Telecommunications work focuses on new protocols and modeling for specific needs, mostly in wireless. Their analysis methods are suboptimal, largely ignoring the modeling advances of recent. And modeling focuses on marketable tools.
- Operations Research community focuses on new algorithms and more complicated enhancements. Their work applied to very general, unrealistic network problems.
- Almost nobody is improving how we design and build communications networks. Is it because so few people have the necessary cross discipline knowledge?
- Rare but most useful work crosses these boundaries.
- Trends in telecommunications toward commodity hardware
  - OTN
  - Cloud, xAAS
  - Software Defined Networks and OpenFlow
  - Wireless networking, access



Reliability Community

- Source-Sink Availability
- Source-All Availability
- All-All Availability
- All paths are viable



- Some extend to capacity constrained, but never considering the capacity as a limited resource.

Telecommunications Community

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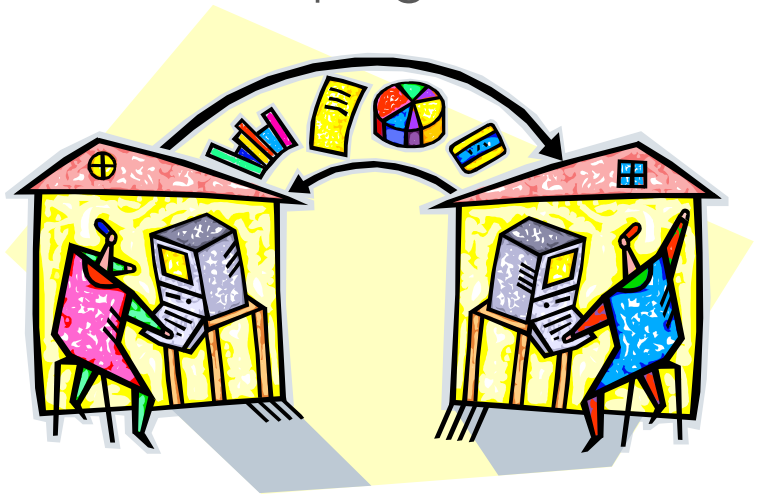
- If they model, estimate (usually via simulation) an approximate availability for a specific situation and use case.
- Often considering many of the real world constraints, but inaccurate and inefficient in computational results, and optimized for limited use cases.
- Focus is more on network implementation, with reliability issues as a condition, or at times helping a network find another path.



The Situation

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- Reliability and modeling community comes from the "any path" perspective, whereas the telecommunications community comes from the "best path(s)" perspective.
- A network is built to support many other networks and services, many of which will have differing path perspectives, and most not able to take full advantage of all paths. Protocols matter, but networks are a mix of several, not one or a few. In the future, with xAAS and SDN, it gets worse.
- So what is the right approach? Performability? Mission Reliability? Use Cases?

Practical Problems

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- Multiple connection points to a network
- Multiple connections for a mission need
- Best routing for diverse paths
- Network planning for capacity and availability
- Adding diverse paths

Appropriate Approach

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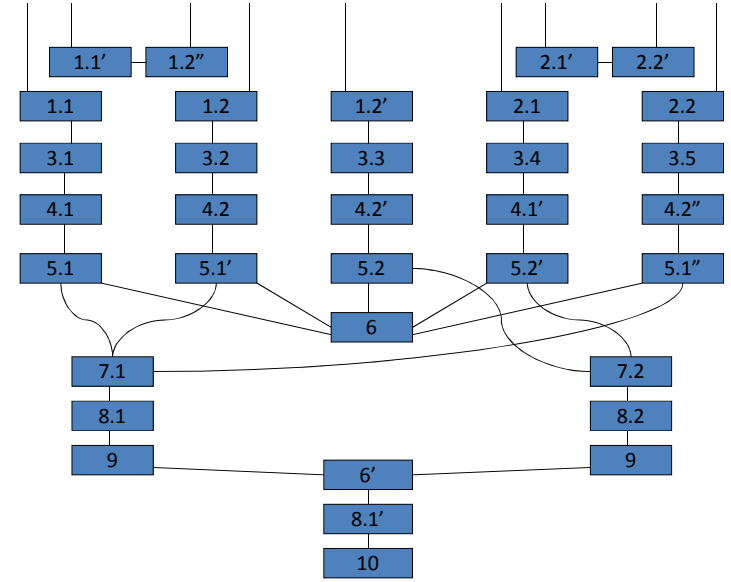
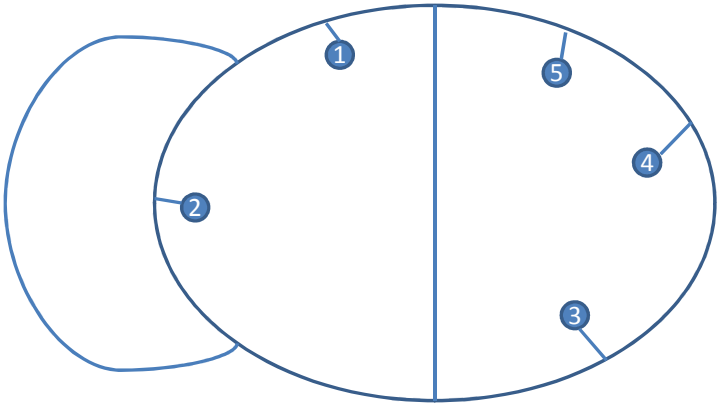
- Algebraic solutions are too complicated for any meaningful network problem.
- We need to compute paths in order to select paths and consider capacity constraints correctly.
  - Cut sets are popular for calculation, but are not useful against real problems with routing.
  - Path set approaches are not as developed, but there are very good approaches available.
- Calculating path sets is usually a very small part of the computation time, and only needs to be done once. Efficient methods here are important, but not the most important.
- Re-computing a network performance or availability for every change is not practical, so pre-computing and leveraging those results is necessary.
- Pure Monte Carlo approaches are very inefficient. Target likely cases and outright calculate them, then use MC approaches to sample the unlikely.
- Different traffic routes through a network differently, so we build failing nodes that shadow a lead node. This approach allows us to handle correlated failures of any type.
- Considering capacity means we cannot assume the network is coherent.
- A measure of independence is useful and fairly new.
- The methods we select have to be practical and useful for multiple layered, multiple protocol, complex networks, not just examples.

Examples





- Numbered nodes in the "fish" network below might look somewhat like the block diagram above.
- Junctions may look similar, and there may be connection points between with complexity as well.
- True connections on the "fish" we consider would look even more complex, with parallel hardware connected through the same conduit , or completely diverse.
- Complexity upon complexity!

Example Approach for Performability

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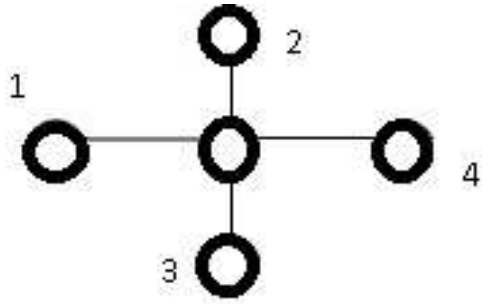
- Depth first exhaustive search to find all A-Z paths possible
  - May require ***hierarchical paths***.
  - First find end points, and stopping conditions, then search paths on depth first search.
- Sort paths to model protocols.
- Divide the network state space into likely few cases, and unlikely many.
- Model the likely few cases for performance, then use Monte Carlo to sample the unlikely cases for performance.
- Tally each source to sink and source to sink connection pairs' outcomes to build the network availability and performance results.
- Post calculations as needed.



Example Outcome

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Avail.	1-2	1-3	1-4	1-5	2-3	2-4	2-5	3-4	3-5	4-5
1-2	0.999585	0.999138	0.999115	0.999254	0.999138	0.999115	0.999254	0.999085	0.999054	0.999031
1-3	0.999138	0.999338	0.999077	0.999131	0.999138	0.998877	0.999031	0.999077	0.999131	0.998869
1-4	0.999115	0.999077	0.999315	0.999108	0.998877	0.999115	0.998908	0.999077	0.998869	0.999108
1-5	0.999254	0.999131	0.999108	0.999454	0.998931	0.998908	0.999254	0.998954	0.999131	0.999108
2-3	0.999138	0.999138	0.998877	0.998931	0.999354	0.999092	0.999146	0.999092	0.999146	0.998885
2-4	0.999115	0.998877	0.999115	0.998908	0.999092	0.999331	0.999123	0.999092	0.998885	0.999123
2-5	0.999254	0.998931	0.998908	0.999254	0.999146	0.999123	0.999469	0.998969	0.999146	0.999123
3-4	0.999085	0.999077	0.999077	0.998954	0.999092	0.999092	0.998969	0.9995	0.999208	0.999208
3-5	0.999054	0.999131	0.998869	0.999131	0.999146	0.998885	0.999146	0.999208	0.999469	0.999208
4-5	0.999031	0.998869	0.999108	0.999108	0.998885	0.999123	0.999123	0.999208	0.999208	0.999446

- Let A, B be connection of different i-j.
- P(A), P(B) are on the diagonal.
- P(A ∩ B) are on the off diagonal.
- We can do much with this set of results!

Typical Decision Support

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- Overall network statistics from weighted averages
- Mission availability estimates from specific outcome combinations
- Connecting new nodes to the network
  - In series with the network: P(E)*P(C)*P(A)
  - Dual paths to one node to one destination:
    P(E)*(1-(1-P(C))*(1-P(D)))*P(A)
  - Dual paths to one node to either of two destinations:
    P(E)*(1-(1-P(C))*(1-P(D)))* P(A∪B)
  - Dual paths through:

    P(E)*(P(C)*P(A)+P(D)*P(B)-P(C)*P(D)* P(A∩B)).

Network Independence

$$r_{AB} = \frac{\sum A_i B_i - n\mu_A\mu_B}{(n-1)S_A S_B} = \frac{P(\hat{A} \cap \hat{B}) - P(\hat{A})P(\hat{B})}{\sqrt{P(\hat{A})(1-P(\hat{A})}\sqrt{P(\hat{B})(1-P(\hat{B})}}$$

- Sample correlation coefficient above can be simplified to just look at the numerator:

$$P(\hat{A} \cap \hat{B}) - P(\hat{A})P(\hat{B})$$

- Positive correlation means sharing failure modes, no correlation means independent (most desirable), and negative correlation is non-coherent but could be a good performability situation.

Example results

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- As expected, more diversity yields better availability.

Dual Homing Availability, End to End			
Network	dual links	dual rails	dual routes
Availability	0.9976662	0.9976893	0.9978584

- And as expected, more diversity makes nodes more independent as well.

Avgerage location to location correllation coefficients			
Network	dual links	dual rails	dual routes
Corr. Coeff.	0.4387507	0.4379968	0.4082457

Thank you!

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- Much of these elements are available on http://rupeuniversity.com
- Comments are always welcome! Either directly, via email at jrupe@ieee.org or on http://rupeuniversity.com