Architectural Musings on SDN
("and now for something completely different…")

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Agenda

- Architectural Features that Enable System Scalability and Evolvability
- A Quick Tour Through the SDN Design Space
- Panel

Danger Will Robinson!!!

This talk is intended to be controversial/provocative (and maybe a bit "sciencey")

What are Scalability and Evolvability?

- **Scalability** is robustness to changes to the size and complexity of a system as a whole
- **Evolvability** is robustness of lineages to changes on long time scales
- Other system features cast as robustness
  - **Reliability** is robustness to component failures
  - **Efficiency** is robustness to resource scarcity
  - **Modularity** is robustness to component rearrangements

OK, Fine. But What is Robustness?

- ***Definition***: A *[property*] of a *[system]* is **robust** if it is *[invariant]* with respect to a *[set of perturbations], up to some limit*

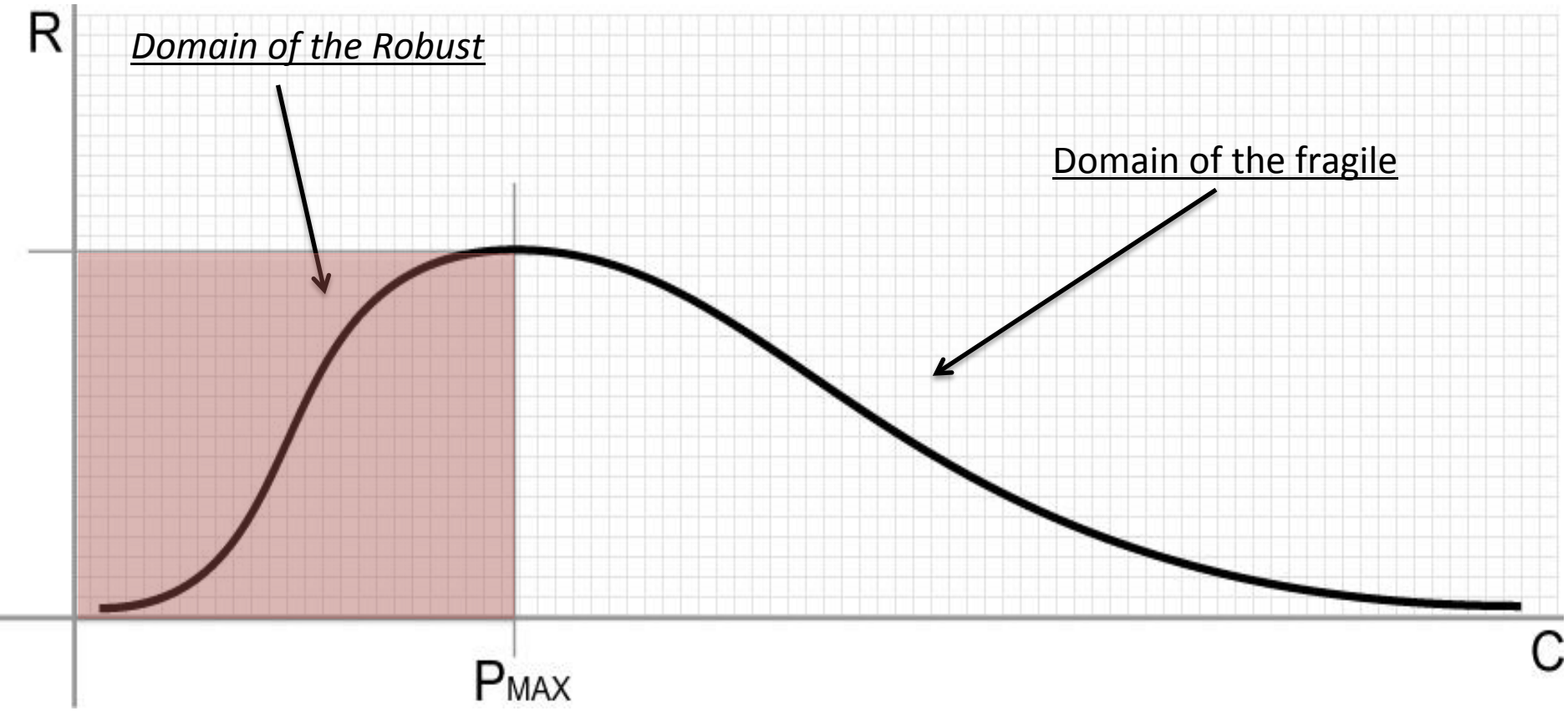
- **Fragility** is the opposite of robustness
  - If you're fragile you depend on 2nd order effects (acceleration) and the curve is concave
  - Catch me later if you'd like to chat further about this…

- A system can have a *property* that is *robust* to one set of perturbations and yet *fragile* for a *different property* and/or perturbation → the system is **Robust Yet Fragile (RYF-complex)** [0]
  - Or the system may collapse if it experiences perturbations above a certain threshold (K-fragile)

- Example: A possible ***RYF tradeoff*** is that a system with high efficiency (i.e., using minimal system resources) might be unreliable (i.e., fragile to component failure) or hard to evolve

[0] http://www.istar.upenn.edu/osw/white paper/John Doyle White Paper.pdf

Robustness vs. Complexity
Systems View



What this curve is telling us iis that a system needs complexity to achieve robustness (wrt some feature to some perturbation), but like everything else, too much of of a good thing….

Ok, but what is *Complexity*?

"In our view, however, complexity is most succinctly discussed in terms of functionality and its robustness. Specifically, ***we argue that complexity in highly organized systems arises primarily from design strategies intended to create robustness to uncertainty in their environments and component parts.***" [AldersonDoyle2010]

BTW, This Might Be Obvious But…

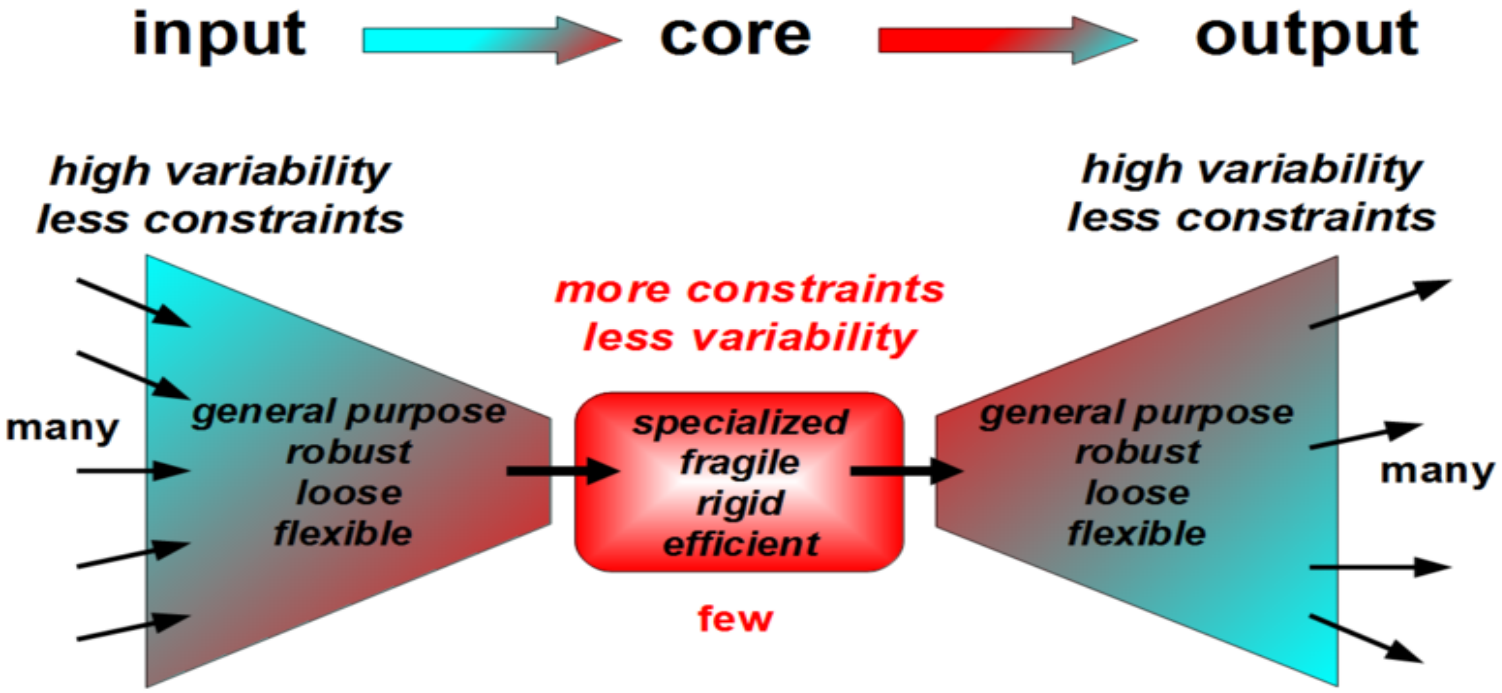
- Networks are incredibly general and expressive structures
- Networks are extremely common in nature
  - Immune systems, energy metabolism, transportation systems, *Internet*, macro economies, forest ecology, the main sequence (stellar evolution), galactic structures, ….
- So it comes as no surprise that we study, for example, biological systems in our attempts to get a deeper understanding of complexity and the architectures that provide for scalability, evolvability, and the like
- Ok, this is cool, but what are the key architectural takeaways from this work for us ?
  - where us \in {ops, engineering, architects …}

Key Architectural Takeaways

- What we have learned is that there are ***fundamental architectural building blocks*** found in systems that scale and are evolvable. These include
  - Bowtie architectures
  - RYF complexity
  - Massively distributed, *robust* control loops
    - Contrast optimal control loops and hop-by-hop control
  - Highly layered
    - But with layer violations
  - Protocol Based Architectures (PBAs)
  - Degeneracy

Bowties 101

Constraints that Deconstrain

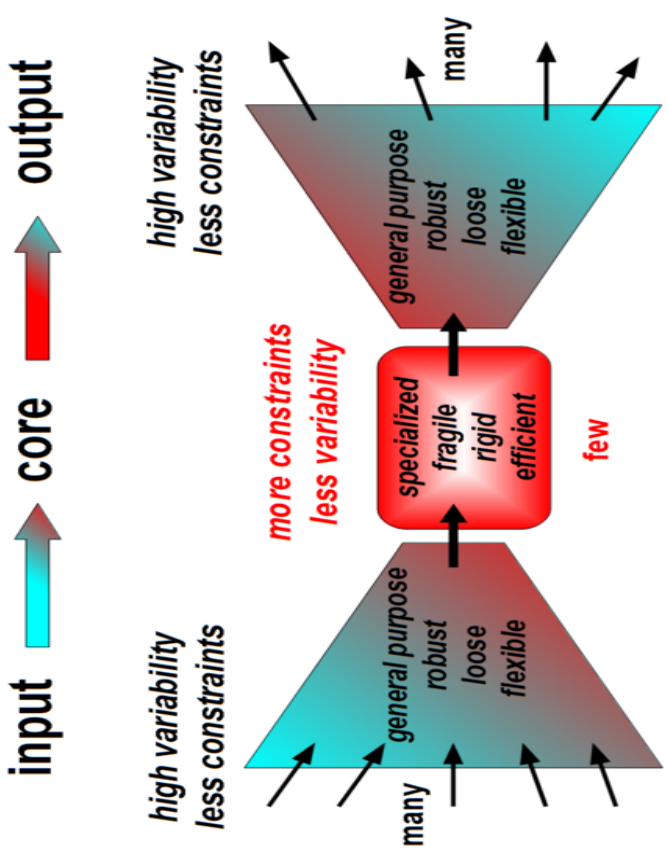


For example, the reactions and metabolites of core metabolism, e.g., *ATP metabolism*, Krebs/Citric Acid cycle signaling networks, …

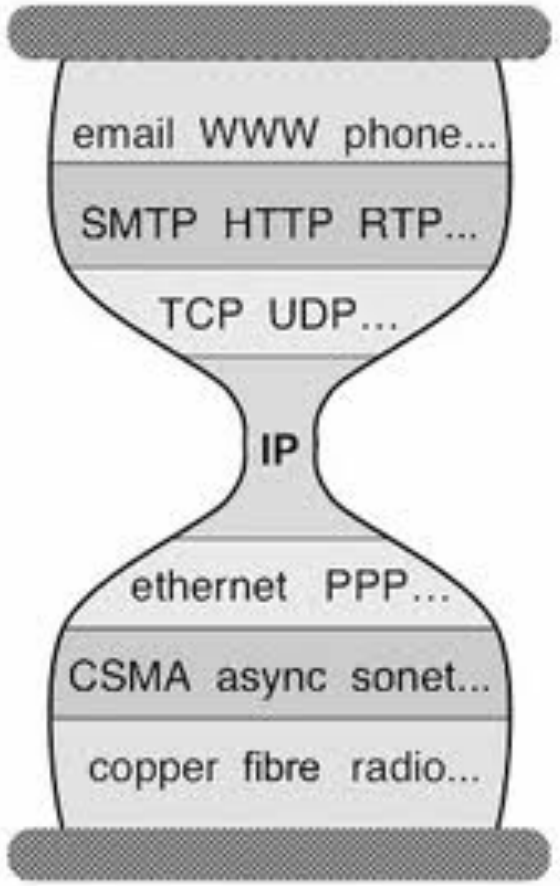
See, e.g., Doyle, et. al., "Architecture, Constraints, and Behavior", http://www.pnas.org/content/108/suppl.3/15624.full

But Wait a Second

Anything Look Familiar?

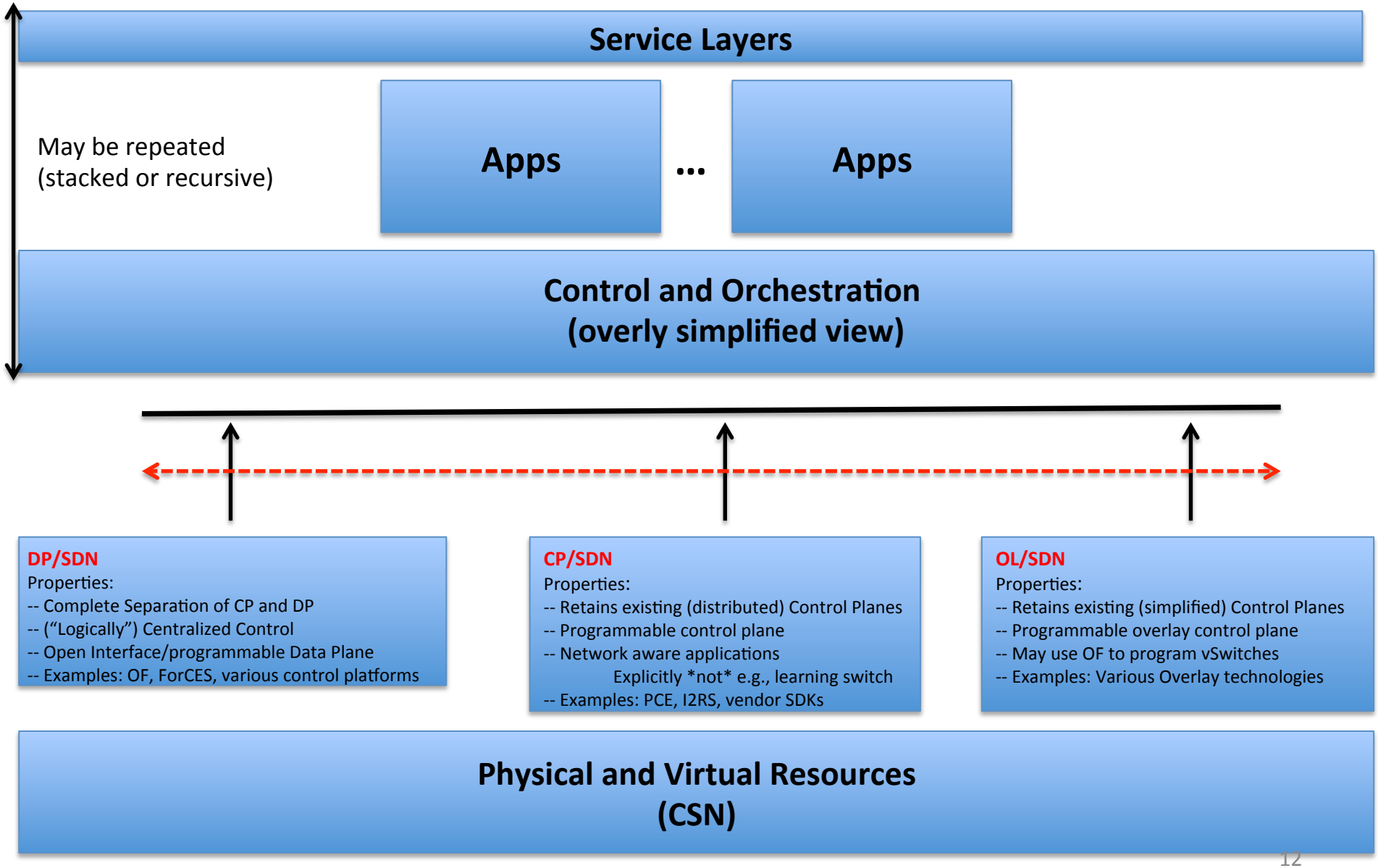


Bowtie Architecture



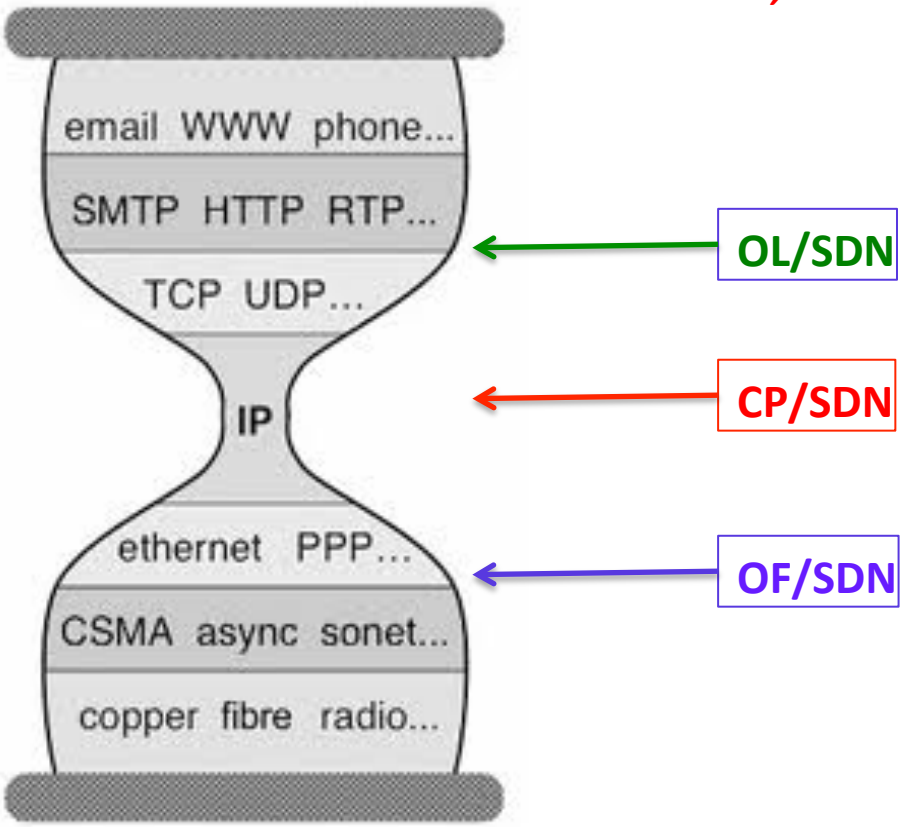
Hourglass Architecture

The SDN Design Space



Putting it all Together

Open Loop Control + s/w + Moore's Law →
Randomness, Uncertainty, and Volatility



- OF/SDN proposes a new architectural waist (not exactly sure where)
- CP/SDN makes existing control planes programmable
- OL/SDN is an application *from the perspective of the Internet's waist*

Finally…What I Hope To Achieve

I hope to convince you that uncertainty and volatility are the "coin of the realm" of the future, why this is the case, how SDN (and the rise of software in general) is accelerating this effect, and finally, what we might do to take advantage of it.[1]

1 s/take advantage of/*survive*/ -- @smd

Q&A

Thanks!