Internet Systems Laboratory

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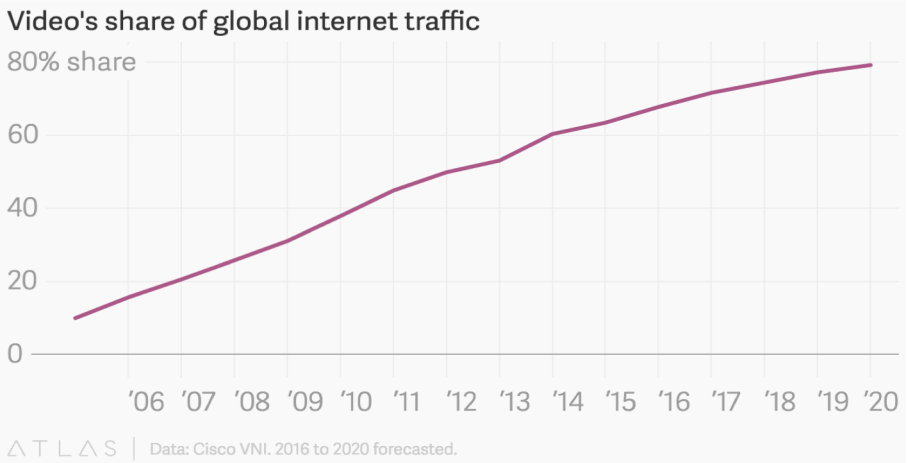
Emerging Network Trends

Year	Global Internet Traffic
1992	100 GB per day
1997	100 GB per hour
2002	100 GB per second
2007	2,000 GB per second
2017	46,600 GB per second
2022	150,700 GB per second



Video dominant portion of Internet traffic

Phenomenal and continued traffic growth
[Cisco Visual Networking Index, Forecast] and Trends, 17-22]

- Over 5 years, 100X increase in traffic, yet performance goals must be met 99.99% of time (vs. 99% of the time) [Google, 2018]
- New demanding applications: 360-degree and 4K video, VR/AR
- Challenges: Network failures, sudden traffic shifts (e.g., COVID -> 62% increase in peak traffic with Comcast), network variability
- Wireless and UAS settings pose unique variability challenges.

#1: Synthesizing networks with provable properties

Research Goals:

- Network design: traditionally ad-hoc, manual-intensive, error-prone.
- Contrast: Tools for chip and software industry a $10B business
- Can we formally certify that a network design meets performance goals?
- How do we synthesize network designs to meet objectives?

Architect objectives:
E.g., "Ensure mission critical traffic sees acceptable throughput under failures that occur 99.99% of the time"

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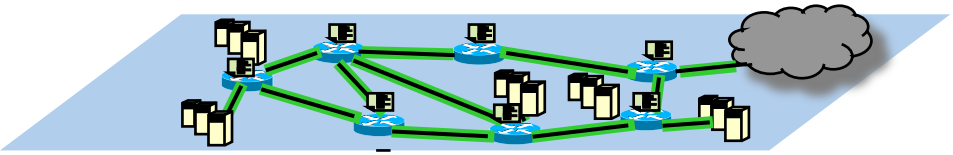
Network design (topology, routing) and configurations



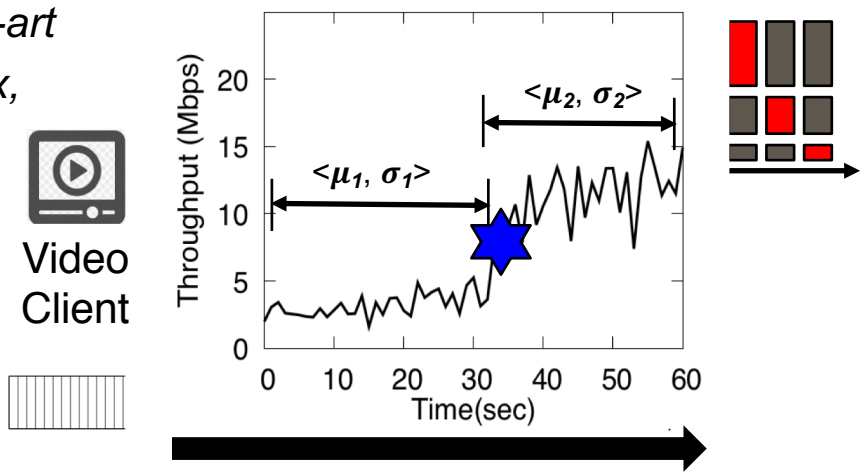
Approach and ongoing research: [NSDI17,Sigcomm20,Sigmetrics20]

- Early work in verifying quantitative network properties (not just correctness)
- Robust optimization and new algorithms to optimize for percentiles (e.g., 99%)
- Formal methods and novel program synthesis approach inspired by networking [Hotnets 19]
- Validations using real network configurations, traffic, and topology data
- Released Purdue configuration data requested by 50+ research groups.
- Collaborators: Prof. Mohit Tawarmalani (Krannert), Prof Xiaokang Qiu (Purdue ECE)

#2: ML-driven optimization of Internet video

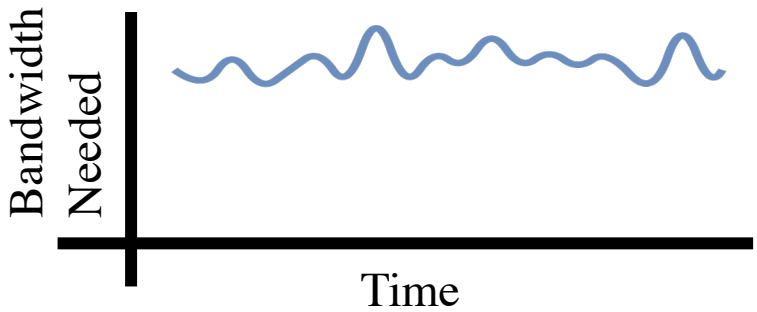
- Data-driven approaches to optimize algorithms for Internet video streaming (e.g., low rebuffering, high bit rates) over variable Internet conditions
- Leverage large-scale data-sets of video sessions from industry, real networks
- Adapt ML techniques (e.g., neural networks for predicting network throughput) ***[Sigmetrics 22]***
- Applications to Unmanned Aerial System (UAS) settings ***[ICNP 21]***
- Tackling "counter-factual questions" (with Prof. Bruno Ribeiro, Purdue CS)
  - Using traces, what is the impact if algorithms changed? ***[NetAI, 2020]***
  - Developing techniques to address "causal biases" in data analysis

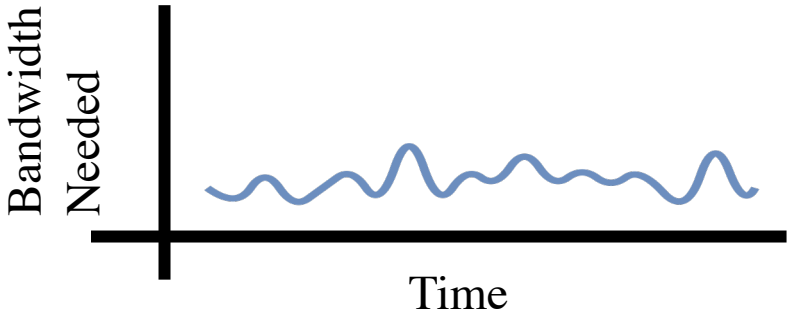
*Oboe (**Sigcomm18**) out-performs state-of-the-art video delivery algorithms (from Stanford/Netflix, CMU and a reinforcement learning approach from MIT) by upto 38% in video delivery metrics*

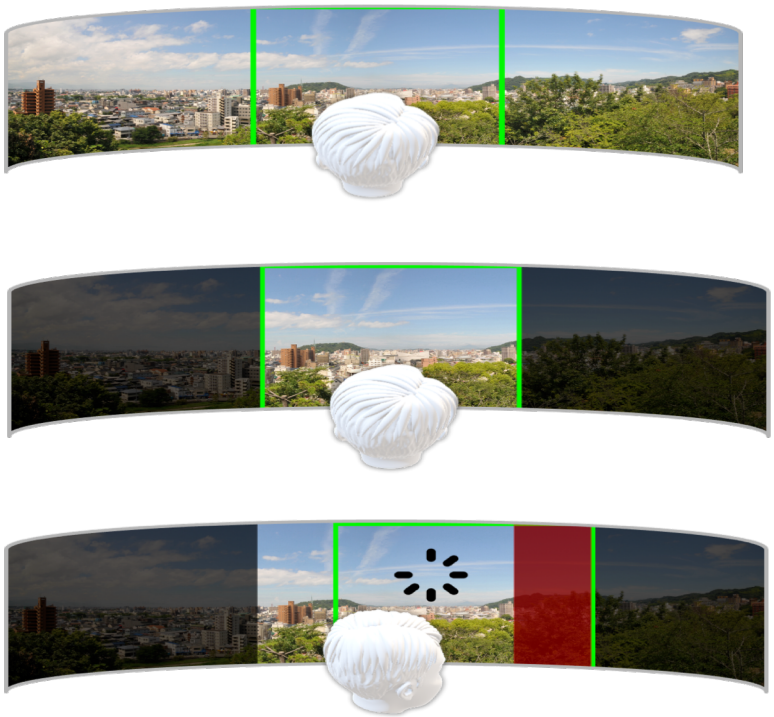


#3: Network support for multi-perspective video

- Redesign Internet video ecosystem for emerging multi-perspective video (e.g., 360-degree, multi-view video, volumetric video)
- Key use case for 5G and future networks
- Challenges: avoid data redundancy, and achieve low latency when switching perspectives
- Holistic approach combining video delivery algorithms, video coding, and how users engage with video. Collaboration with USC and Prof. Quinn (Purdue ECE).







Prospective student questions

- What skillsets will help to succeed in Purdue ISL?
  - Strong Computer Science/Engineering background, strong programming skills
  - EE students with programming background and willing to learn are welcome.
  - Desired:
    - Strong aptitude in building systems [or]
    - Aptitude for applying theory (ML/optimization/formal) to networking
- Where do ISL students go after a Ph.D?
  - Industrial Research (Google, Facebook, AT&T Research, ByteDance)
  - Universities (Ball State University)
  - Government Agencies