Internet Systems Laboratory

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Emerging Network Trends

<table>
<thead>
<tr>
<th>Year</th>
<th>Global Internet Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>100 GB per day</td>
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<tr>
<td>1997</td>
<td>100 GB per hour</td>
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<tr>
<td>2002</td>
<td>100 GB per second</td>
</tr>
<tr>
<td>2007</td>
<td>2,000 GB per second</td>
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<tr>
<td>2017</td>
<td>46,600 GB per second</td>
</tr>
<tr>
<td>2022</td>
<td>150,700 GB per second</td>
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</tbody>
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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?

**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)

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

**Network design (topology, routing) and configurations**
#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) \[\text{[Sigmetrics 22]}\]
- Applications to Unmanned Aerial System (UAS) settings \[\text{[ICNP 21]}\]
- Tackling “counter-factual questions” (with Prof. Bruno Ribeiro, Purdue CS)
  - Using traces, what is the impact if algorithms changed? \[\text{[NetAI, 2020]}\]
  - 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 up to 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