

Network Algorithms: Conclusions

George Varghese

June 12, 2007

Endgame

- *What was the course about?* What were the main problems and how did they arise? What are the main techniques.
- *What is Algorithmics about?* What is the underlying philosophy behind Network Algorithms, and how does it differ from algorithms by themselves.
- *Is Network Algorithmics used in real systems?* Are the techniques in this book exercises in speculation, or are there real systems that use some of these techniques.
- *What is the future of Network Algorithmics?* Are all the interesting problems already solved?

Endnode Algorithmics (by contrast)

- *Computation versus Communication:* Endnodes are about general purpose computing, unknown and varied computational demands.
- *Vertical versus Horizontal Integration:* Many companies supplying subsystems. kernels designed to tolerate unknown and potentially buggy applications.
- *Complexity of computation:* Endnode protocol functions are more complex (application, transport) compared to routers.

4 Artifacts of Endnode Software

- *1. Population Scaling:* For example, simple caches worked fine for route lookups till address diversity and the need for CIDR (both caused by population scaling) forced the use of fast longest matching prefix.
- *2. Speed Scaling:* simple DRAM-based schemes sufficed for prefix lookup (e.g., using expanded tries) till increasing link speeds forced the use of limited SRAM and compressed tries.

Course Review

What Algorithmics is about

- **Definition:** Network Algorithmics is the use of an interdisciplinary systems approach, seasoned with algorithmic thinking, to design fast implementations of network processing tasks.

Interdisciplinary Thinking

Systems Thinking

- Moving functions in either *space* or *time*.

Algorithmic Thinking

Trie Search, HyperCuts. Caveats:

- *Wrong Measures:* e.g., number of memory accesses not operations. bitmaps vs, heap
- *Asymptotic Complexity:* Asymptotic complexity hides constants .
- *Incorrect cost penalties:* Updates do not matter

Real Products

- Hashing: Gigaswitch
- IP Lookups: Tree BitMap
- Classification: HyperCuts
- QoS: DRR

Cisco GSR

- *Switch:* iSLIP
- *IP Lookups:* Multibit Trie
- *QoS:* DRR and Token Buckets and weighted RED
- *Classification:* RFC

Future Challenges

- *New abstractions:* TCP Offload, XML processing, new Internet services like Google, Amazon (beyond servers), CORBA, SSL.
- *New Connecting Disciplines:* Learning theory, databases, statistics.
- *New requirements:* Reliability, maintainability, low power.

Bottleneck	Chapter	Cause	Sample Solution
<i>Exact Lookups</i>	10	<i>Link speed scaling</i>	<i>Expanded multibit tries</i>
<i>Prefix Lookups</i>	11	<i>CIDR, link speed scaling Prefix database size scaling</i>	<i>Expanded multibit tries Compressed multibit tries</i>
<i>Packet Classification</i>	12	<i>Service differentiation Link speed and size scaling</i>	<i>Decision trees and heuristics Hardware parallelism (CAMs)</i>
<i>Switching</i>	13	<i>Electrical scaling of busses Head of line blocking Scalibility in # of ports</i>	<i>Crossbar switches VOQs, fast approximate matches Hierarchical fabrics, randomized resource contention algorithms</i>
<i>Fair Queueing</i>	14	<i>Service differentiation in Link speed scaling Memory scaling</i>	<i>DRR, fast heaps SFQ, DiffServ, Core Stateless</i>
<i>Internal links</i>	15	<i>Electrical scaling of busses</i>	<i>reliable striping, flow control</i>
<i>Measurement</i>	16	<i>Link speed scaling, # of counters</i>	<i>Low order bits in SRAM + DRAM Juniper's DCU</i>
<i>Security</i>	17	<i>Scaling in number and intensity of attacks</i>	<i>Traceback with Bloom Filters Frequent content based worm detection</i>

ENDNODE ALGORITHMICS

Discipline	Example
<i>Networking</i>	<i>Header Prediction (Chapter 6)</i>
<i>Operating Systems</i>	<i>Application Device Channels (Chapter 6)</i>
<i>Computer Architecture</i>	<i>Locality Driven Receiver Processing (Chapter 5)</i>
<i>Algorithms</i>	<i>Timing Wheels (Chapter 8)</i>

ROUTER ALGORITHMICS

Discipline	Example
<i>Networking</i>	<i>Link striping (Chapter 15)</i>
<i>Hardware Design</i>	<i>Switch arbiters (Chapter 2 & 10)</i>
<i>Algorithms</i>	<i>Fast IP Lookup (Chapter 12)</i>

