Seeding a Community Cloud Through End User Participation

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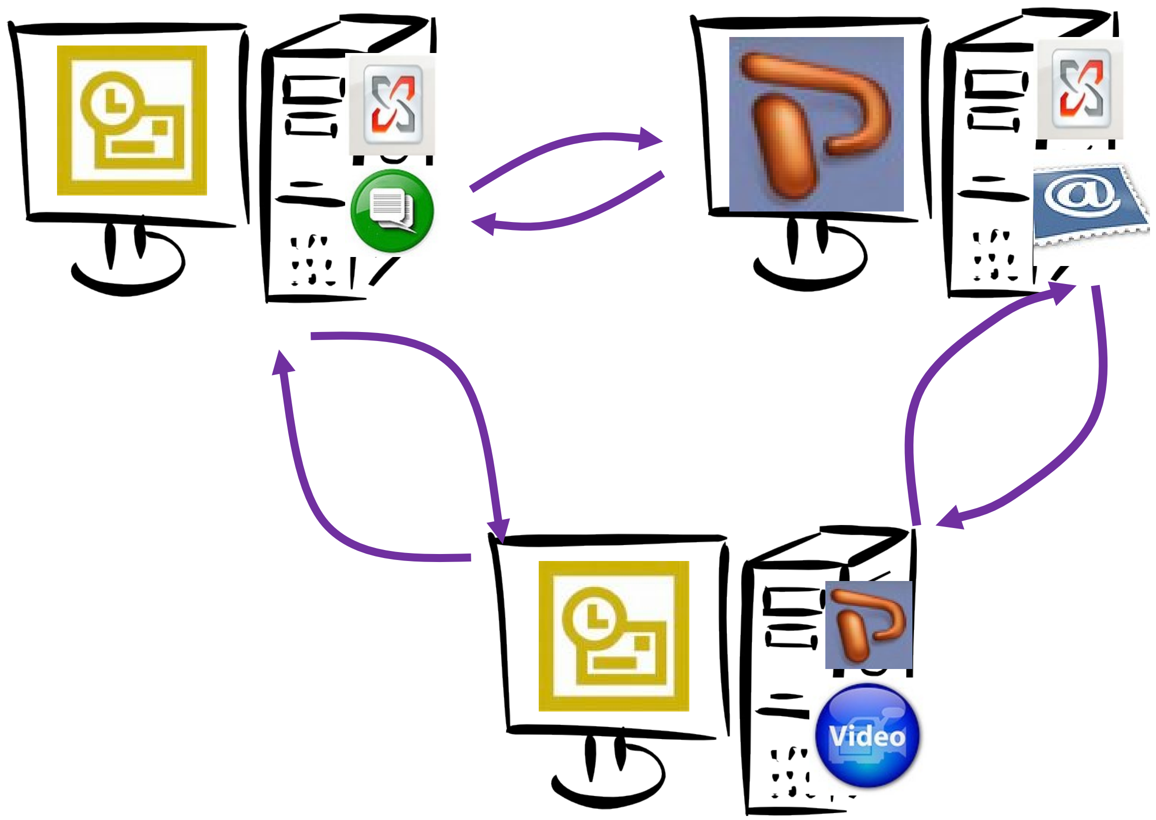
Vibrant Ecosystem …

Or Squandered Resources?

Our Vision



Commoditize Resources on End Hosts

Why Are End Hosts Useful?

- 3-4 orders of magnitude more end hosts
- P2P responsible for about 38% of Internet traffic [Cisco 2009]
- BitTorrent has 100x more distribution capacity than YouTube
- 15-30% of web traffic comes from the edge of the network [Akamai]
- Lots of growth and focus at the edges
- Proximity necessary to minimize latency
  - The speed of light isn't improving!

Seattle Model

- Scales with demand for free
- Developers and end users have power
- No vendor API lock-in

[Cappos SIGCSE 09, Seattle website]

Our First Step

- Build a testbed from end hosts!

Seattle Testbed

Open peer-to-peer application hosting

- Unknown users donate resources (VMs)
- Unknown developers push code
- Tit-for-tat like model for resource sharing
- Commonly used like a P2P PlanetLab

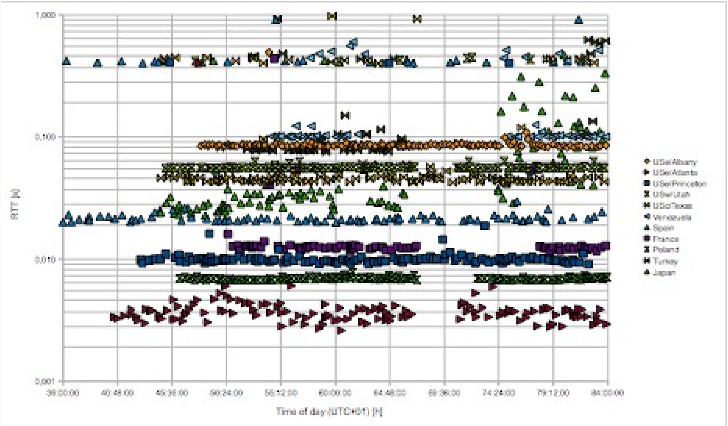
https://seattle.cs.washington.edu

Educational use

- Classroom experience
  - Released in Spring 2009
  - Used in almost two dozen classes (more in progress)
  - 3 tutorials, 3 library references, etc.
  - 8 battle tested assignments
    - Overlay routing, flow control, NAT / Non-transitive connectivity, Chord (DHT), reference monitors, etc.
    - Security, OS classes are coming
  - Advanced projects
    - MapReduce, Distributed Web Servers, etc.

- Community support
  - Supported by educational groups
  - SIGCSE paper, several workshops, etc.
  - Top ranked SIGCOMM Educational Resou
  - Coming in Computer Networking by Kurose & Ross
    - Most popular networking book!

Research use



- Projects
  - YouTube CDN mapping
  - Wireless mobility patterns
  - Network heterogeneity
  - Overlay routing across P2P networks
  - P2P resource allocation fairness
  - Multiple top conference paper submissions

- Community support
  - Port to N900 by Nokia researchers
  - Runs on PlanetLab, Emulab, GpENI, DOME, etc.
  - GENI workshops, PyCon, etc.
  - NaCl integration by U Victoria / HP Labs
  - iPad 2 port, tun / tap support, Android, etc. by academics in Europe

Commercial use

- Projects
  - CDN
  - P2P Backup
  - OpenFlow cloud control
  - Single Cloud Image
  - Zenodotus service
  - End user web hosting

- Community support
  - Network troubleshooting by U Victoria / HP Labs
  - Extra traff c relays for Tor (pending)
  - CDN for major content provider (pending)
  - AppStore for networks (pending)

Commercial use is very early stage!

Current Node Composition

Node Type	Quantity*
Testbed	791
University nodes	1720
Home machines	2849
Phone in name	67
Unknown nodes	3370
Total	8797

About 1% phones, 9% testbed, 20% university, 71% (likely) home nodes

* Nodes by IP address that accessed the Seattle software updater from Nov 2010 to Nov 2011. Location information by pygeoip.

Demonstration

Typical Seattle Workflow

- Registration
- Download installer
- Demo HuXiang
- Acquire resources
  - Use SeattleGENI website
- Deploy all pairs ping
- Use shell to locate and control resources

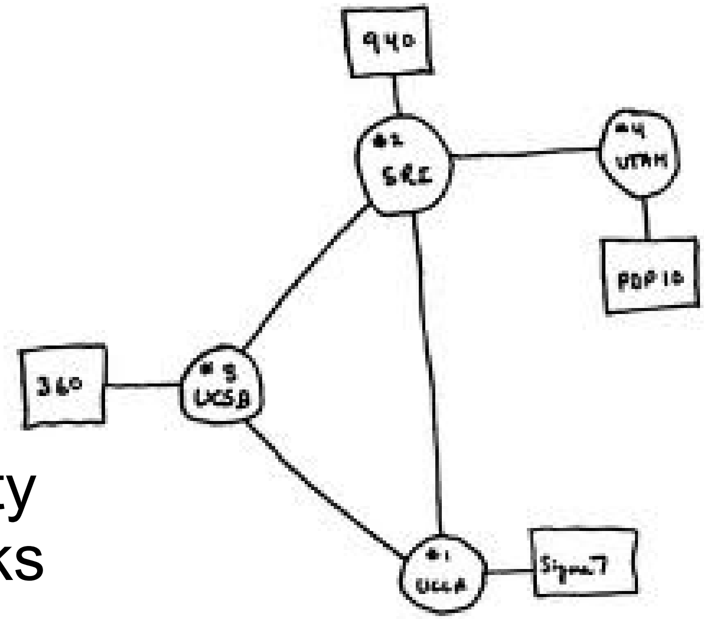
Demo HuXiang!

Seattle Research Challenges

- Network Heterogeneity
  - This talk!
- Need to execute untrusted code on end hosts
  - RepyV2 Security Layers [Cappos CCS 10]
- Performance isolation
  - Repy VM
- Heterogeneous OSes → uniform VM
  - CheckAPI
- Legacy code → sandbox isolation
  - Lind
- Need support for fault-tolerance and scalability, resource allocation, incentives, usable policies, …

A Long Time Ago...

- The Network was simple
  - Nodes had fixed locations
  - Every node had a public IP
  - Relatively little heterogeneity in device types and networks
- Applications used a (semi-)standard API
  - Berkeley / BSD Socket API



Today...

- The Network is complex
  - Nodes move around
  - Many nodes behind NATs / Firewalls / IPSes / proxies
  - Diversity evident throughout devices and networks
  - Tomorrow will be worse!
- Applications **<u>still</u>** use the (semi-)standard API
  - Berkeley / BSD Socket API

How Do Programmers Deal With Network Diversity?

- Network libraries
  - Usually target a single issue
    - Rarely a few related items
  - Change API semantics
    - Require porting the application
      - Hence usually only done for 'popular' configurations
      - Focus on availability, not optimality
    - Complicate debugging

Multiple problems often co-exist!

Can We Use Multiple Libraries?

- Network libraries
  - Semantics change subtly
    - Each library has slightly different semantics / behaviors
  - Combining means porting one to the other
    - The order matters
    - You may have to port both directions

Are Multiple Libraries Needed in Practice?

Skype

- Forward Error Correction.
- NAT traversal.
- Mobility support.
- Checks rate limiting
- Variable bit-rate compression
- Encryption
- Disconnection / reconnection (New!)

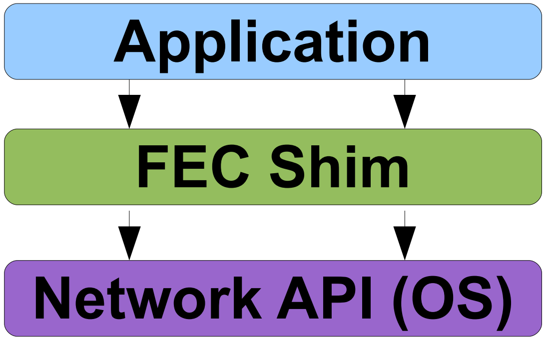
Why Hasn't The API Evolved?

- Applications need to be backward compatible
  - Networks too!

What Are Our Goals?

- Add functionality
  - Must add value
    - Composability
    - No ordering constraints
- Transparency
  - No application changes
  - No network changes
- Correctness
  - Semantic bugs must be easy to pinpoint

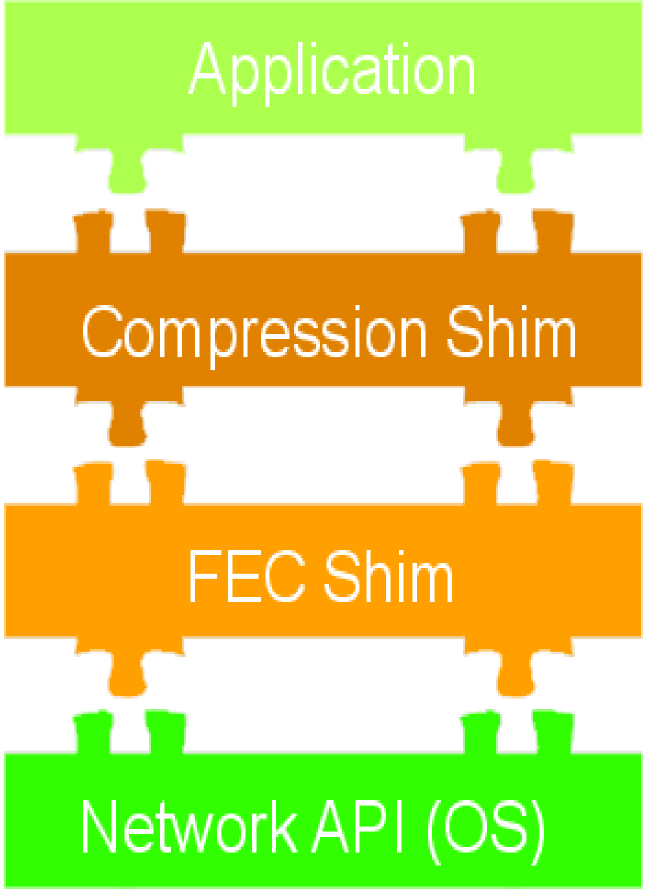
Shims



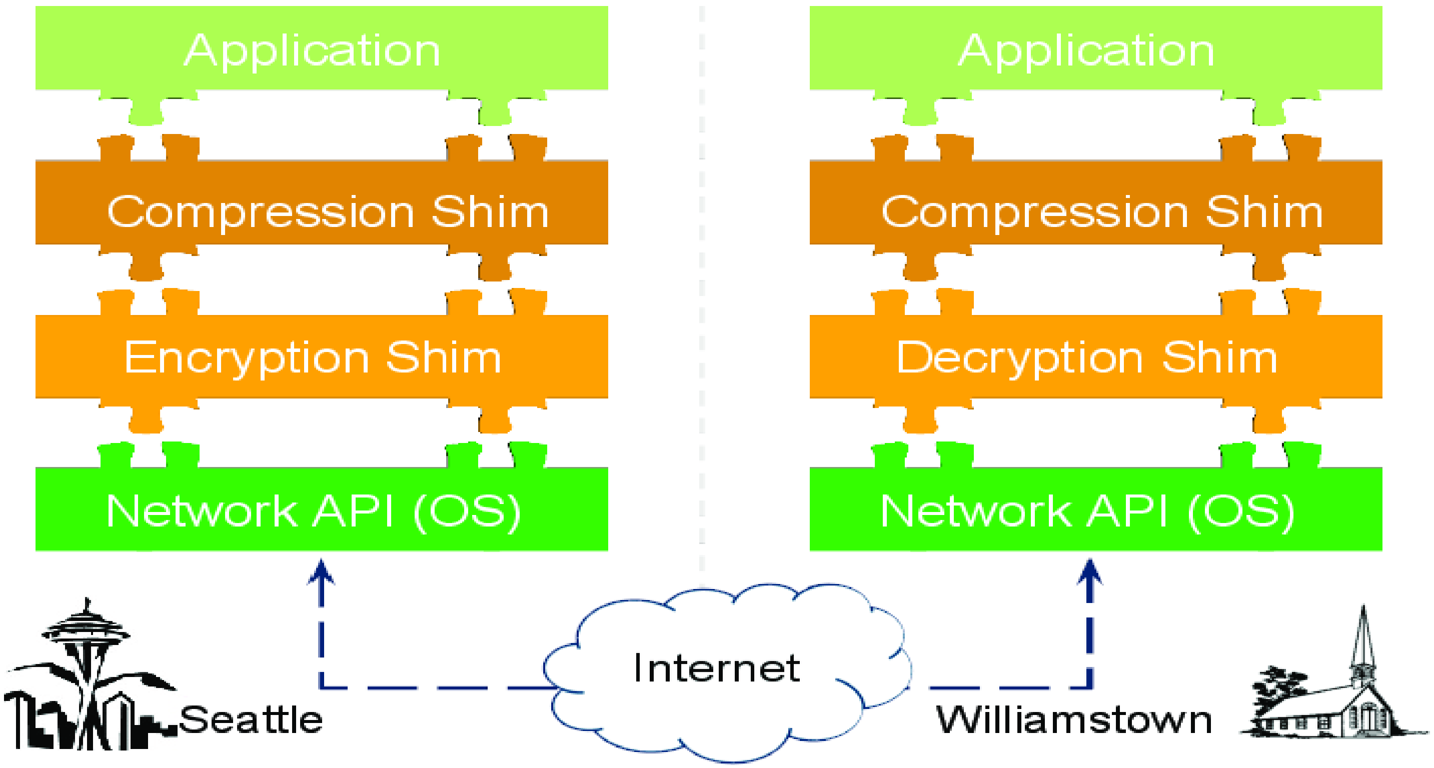
- Adds functionality while enforcing semantics.
  - Verification using novel modeling techniques
  - Ensures application need not be modified
- Instantiated per connection / datagram.
  - Inserted between app and net API.
- Compatible with legacy everything
  - Even when one sided
    - … early adopters still can benefit!

Networks are complex

- We want to use multiple shims together!
- Build a shim-stack
  - Push, pop, etc.
- Any shim stack is transparent because of **semantic consistency**.



Balancing a Shim Stack



What Have We Done?

- ~20 shims (needed for Seattle)
  - NAT Traversal, Mobility, FEC, Encryption, One-hop detour, compression, ...
- Multiple ways to connect applications
  - Proxy, LD_PRELOAD
- Legacy hooks
  - Map DNS names to shimstacks via DHT
    - Layers nicely into the Internet
- Taxonomy: Split, Branch, Decider

Real-World Scenario: FEC Shim

- Works well on a network with excess bandwidth and high loss rate.
- Tested on WiMAX testbed which showed lossy network behavior.

Average packet loss ratio (%) by shim and by packet length

Packet Length (Byes)	Shim		
	FECShim ,2	FECShim ,3	NoopShim
400-799	1.042	1.143	2.623
800-1199	1.602	1.773	3.279
1200-1600	1.659	1.935	5.467

Observed packet loss was reduced by more then half when using FEC shim.

Shims with Legacy Application

- Added FEC to VLC using shims
  - Resolved a 5 year old feature request
  - Lines of code changed: **0** (proxy)

Without FEC

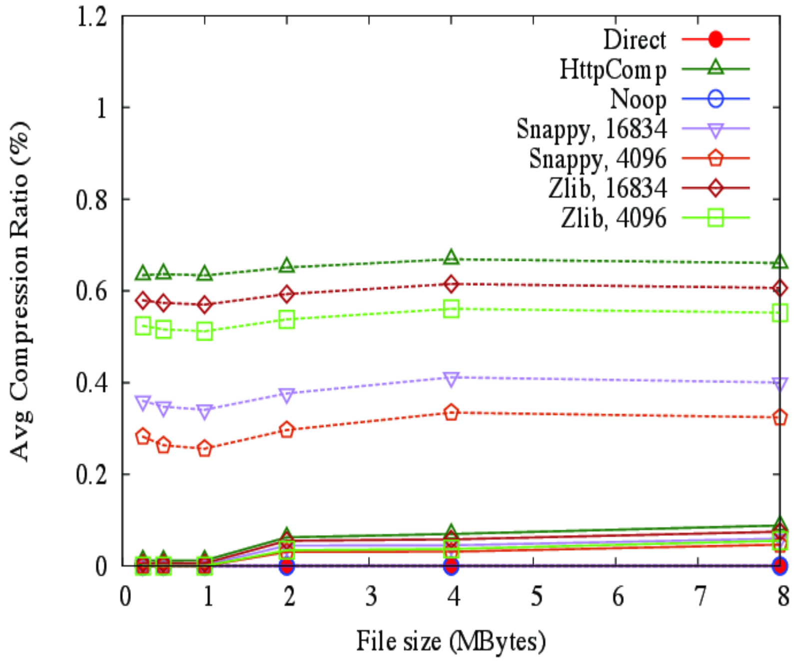
With FEC shim

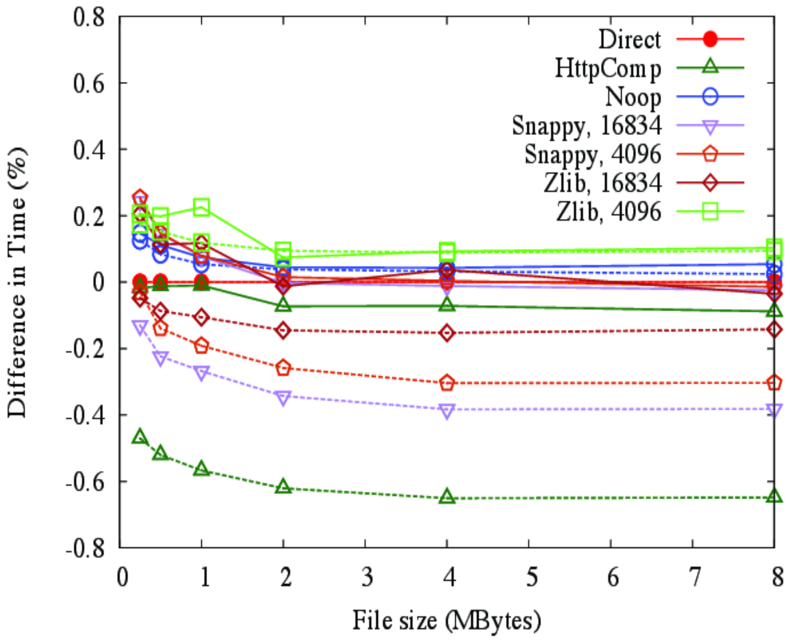
Real-World Scenario: Compression Shim

Experimental setup:

- Apache file server hosting files of various size and type.
- Client downloads files multiple times using wget.
- Redirect network traffic through a shim capable proxy.
- Download files using shim capable proxy vs direct connection.

Real-World Scenario: Compression Shim





Dashed lines represent text files and solid lines represent PDF files.

Stacking Multiple Shims

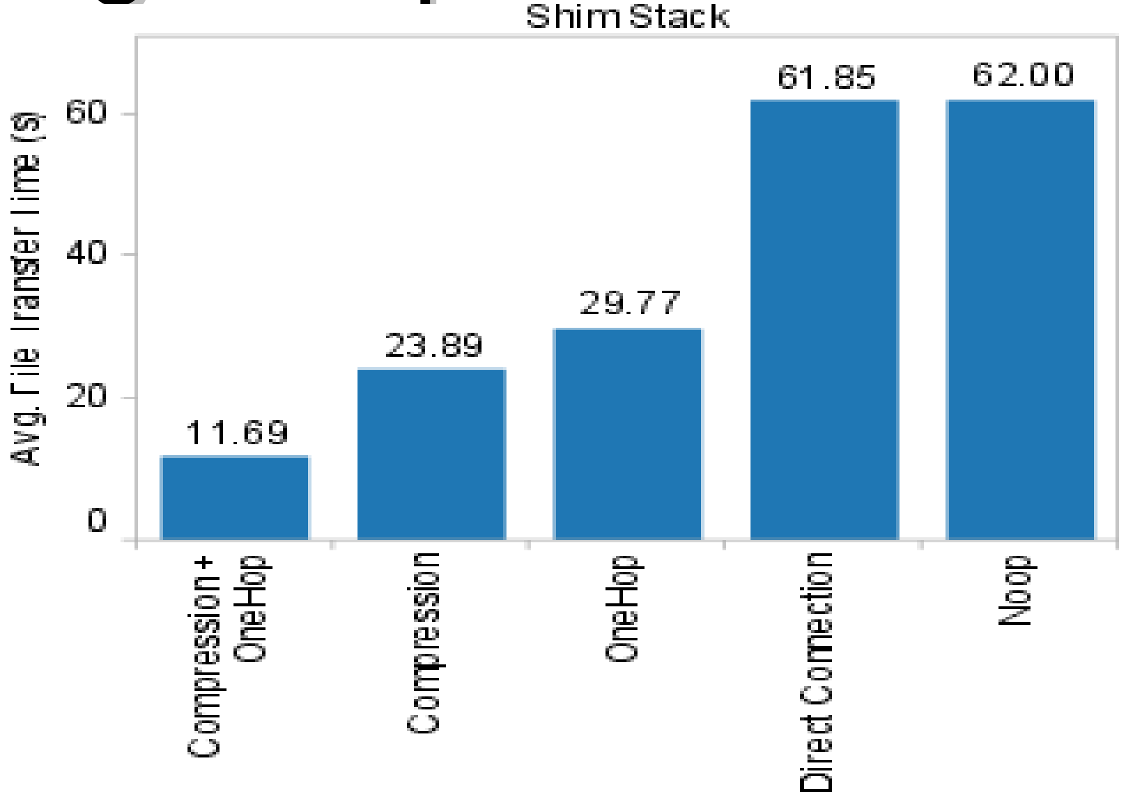


Figure shows average time to transfer a 4MB file. The Compression shim and the OneHopDetour shim individually show improvement over direct connection and Noop shim. However combined together Compression shim + OneHopDetour shim reduces transfer time more then each individual shim!

Conclusion

- Network is complex
  - Need to add functionality to apps
- Shims preserve semantics
  - Applications work!
  - Shim stack combines functionality.
- Shims help applications in real environments!
- Backwards compatible with the Internet

Software Provisioning Work

- Application monitoring [NSDI 08] and redeployment [MIDDLEWARE 2009]
- Package management for the cloud [USENIX 2005, LISA 2007]
  - Package manager / software updater security:
    - mirrors [CCS 08]
    - key compromise [CCS 10]

Future / On-going work

- TUF https://www.updateframework.com
- Automatic detection of mirror misbehavior
- upPIR -- Privately retrieving content

Seattle testbed

- Real system deployed around the world
  - Geographic diversity, network diversity, device diversity...
  - Lots of devices
- Battle tested educational platform!
- Good research platform

(6 papers published, many more on the way / under submission)

- Interesting research problems
  - Portability
  - Network Heterogeneity
  - Legacy cloud containers (SFI meets Seattle VM)
  - Etc.

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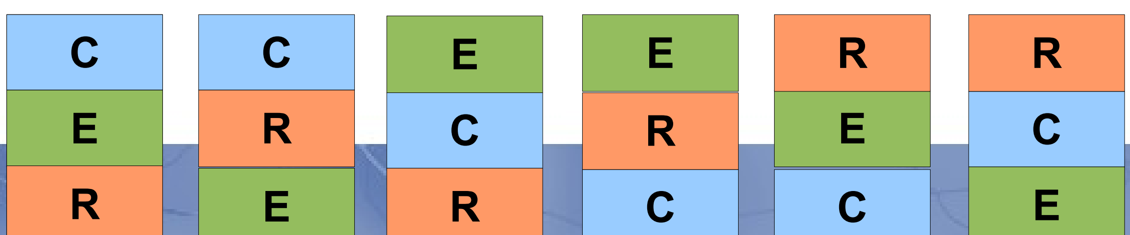
Verifying Semantic Consistency

- Use CheckApi Shim – a model-based testing.
  - Ensures that a shims response to a network call is consistent with the expected behavior of the network API.
- Ensure shims can be stacked in any permutation and still be transparent to the application.



C = Compression-zlib
E = Encryption-rot
R = RateLimit

Example Shims

Shim	Description	LOC
CheckApi	Validates network API semantics	725
Coordination	Builds a balanced shim stack	128
Compression	Compresses data using zlib or snappy	201
DataLimit	Restricts volume of traffic over a period	78
RateLimit	Restricts bandwidth utilized	112
ForwardErrorCorrection	Writes error recovery UDP datagram	129
Logall	Logs all network calls and traffics	162
Duplicate-UDP	Sends data over multiple shimstacks	139
Splitter-TCP	Splits data, favors fast shimstacks	274
NAT-TURN	TURN-like protocol for NAT traversal	139
One-Hop-Detour	Routes traffic through a relay	98
Encrypt-rsa	Encrypts traffic using RSA	206
Encrypt-rot	Encrypts with a Caesarean cipher	16

Coordinating Shim Stacks

- Subproblem: Describing a shim stack
  - Serialize and transmit the string.
- Global naming service allows coordination.
  - Essential for nodes that can't talk directly.

NodeA: “(ShimA)(ShimB,ShimB_args)”
NodeB: ”(ShimD)”
NodeC: “(ShimD)(ShimA)”
.
.
.

DHT server with key value pair.

Network Flow in Shimmed App.