NET WORKING?

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The definition of a USM is joint work with M. Karsten, S. Prasad, and O. Beg
A typical exchange

I can’t get to CNN.com, can you?

Yes, I can…

Oh…
50 ways to lose your connection

- Link failure
- Router failure
- NAT table overflow (SIGCOMM 2011)
- Wire unplugged
- Network congestion
- DNS server failure
- Mis-configured firewall
- Incorrect browser setting
- Personal firewall misconfiguration
- Error in antivirus program
- Wireless AP failure
- Transient routing fault
- ...
Intuition

- Ability to establish an end-to-end connection depends on many underlying systems functioning ‘correctly’

- How to model this?

Universal Switching Machines
Universal Switching Machine

Input port

Output port

Controller

Drop port

Local state (forwarding table, …)

Actions
1. forward, with modified headers
2. drop
3. consume
4. generate

Packet

Header

Body

details in “An Axiomatic Basis for Communication, Karsten et al, Proc SIGCOMM 2007”
A network of USMs
Fundamental questions

- **Reachability**
  - will a packet from USM A get delivered to USM B?

- What does ‘delivered to B mean’?
- What destination name should A use?

- What port should A use to reach B?
- What state at intermediate USMs is required?
- How is this state created?

- Naming

- State creation
Naming
What’s in a name? That which we call a rose
By any other name would smell as sweet
The name of the song is called "HADDOCKS' EYES."

'Oh, that's the name of the song, is it?' Alice said, trying to feel interested.

'No, you don't understand,' the Knight said, looking a little vexed. 'That's what the name is CALLED. The name really IS "THE AGED AGED MAN."

'Then I ought to have said "That's what the SONG is called"?' Alice corrected herself.

'No, you oughtn't: that's quite another thing! The SONG is called "WAYS AND MEANS": but that's only what it's CALLED, you know!' "Well, what IS the song, then?" said Alice, who was by this time completely bewildered.

'I was coming to that,' the Knight said. 'The song really IS "A-SITTING ON A GATE": and the tune's my own invention.'
...which one will respond to ‘Rose!’
Name for self

• Let A’s name for itself be ‘a’
  • A accepts packets with ‘a’ in header
  • Similar to an accepting state in a Turing Machine

• More precisely:
  The bit string
  which, when present in the destination field of a packet,
  when the packet is present at the $i^{th}$ input port of USM A
  causes the packet to be delivered to the controller port of USM A
  is a name for A at that port
Definite and broadcast names

- Assume that every USM accepts the name ‘*’
  - allows broadcast

- A **definite** name for A is a name for it other than ‘*’
Namespace

- At any USM A,
  - (non-unique) name for B at A is written $b_a$
    - can be a source route

- The namespace at A is the set of definite names it has for every other USM
  - $b_a$, $c_a$, $d_a$, $e_a$ …
Some comments

- Names and addresses are treated alike

- A USM can only be sure of its own name for itself
  - We have to assume that USMs do not lie about their names
Aside

- For global reachability, there must exist at least one shared global namespace $G$

This can be used to set up temporary names (e.g. VCID) or for translation.
Hypothesis

Reachability in a network of USMs corresponds to computability in a UTM
State creation
Three problems

- How does a USM learn of the definite name for another USM?
- Given a name, what output port to use?
- How to install state in intermediate USMs?

Routing using announcements simultaneously solves all three problems!
Name announcements

- Tells recipient of the existence of a USM with a particular name
  - assuming a bidirectional link, where it came from tells the recipient what path to take
    - abstracts distance-vector routing

Source address is an implicit name announcement
Extension 1

A broadcasts announcements to all its output ports

I can reach B by sending a packet with destination b on port 4
Extension 2

Announcements carry costs

Naturally induces a routing algebra

I can reach B by sending a packet with destination b on port 4 with cost 8
Link announcements

Similar extensions allow population of the forwarding table
Reasoning about net working
A logical approach

- What predicates must hold true for connectivity to be achieved between two USMs?

- Protocols relate logic to networking in the same way that a Von Neumann machine relates Lambda calculus to computing
Approach

- Consider progressively more complicated networks
Simplest possible network

Reachability of B from A requires that

- B is up
- Link is up
- \((b,1)\) is in A’s state (exogenously)
Reachability of B from A requires that
- A, B are up
- Both links are up
- Exogenously introduced state in A and B
  or
  Name announcements generated and processed
  or
  Link announcements generated and processed
One bidirectional broadcast link

- Nearly identical pre-conditions as with a single bidirectional link
Chains
Cycles
Most general network

- General bidirectional mesh with multiple namespaces, policies, and broadcast links
  - a generalization of the prior results
- Can model the Internet including all middleboxes
- Work still in progress…
Gateways are shown with bold outlines.
Related work

• **Naming and Binding**
  - Compositional Bindings in Network Domains, Zave, LNCS 2006

• **Declarative networking**
  - Declarative Networking, Loo and Zhou, Morgan and Claypool, 2012

• **Formal analysis of routing**
  - Metarouting, Griffin et al, Proc. SIGCOMM 2005

• **Reasoning about network properties**

• **Automatic generation of OpenFlow configurations**
  - A Compiler and Run-time System for Network Programming Languages, Monsanto et al, POPL 2012
Potential outcomes

- Automatic validation of network configurations
  - using automatic theorem proving
- Building self-diagnosis into the system
  - Frenetic/NCore
  - NetQuery
Conclusions

• Determining the availability of an end-to-end path is a complex problem
  • Predicate logic offers a way out
• Universal Switching Machine framework brings together several disparate threads
• General theory of networking relates USM and UTM