Enabling an Energy-Efficient Future Internet Through Selectively Connected End Systems

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*"The devil opened up his case and he said: 'I'll start this show.'
And fire flew from his fingertips as he resined up his bow."*

Motivation

- Studies have found .....
  - 67% of office desktop computers fully powered after work hours [14]
  - Average residential computer is on 34% of the time [15]
    - Half the time no one is actively using the machine [15]
- Possible energy savings: $0.8-2.7 billion per year in the US alone [5]

Motivation (cont.)

- Why are these machines fully powered?
  - Sporadic, occasional access:
    - User remote access
    - Administrative access (patches, backups, etc.)
    - Service provider access (set-top boxes, VoIP systems, etc.)
    - Preservation of network state

Motivation (cont.)

- Underlying reason: our networking principles

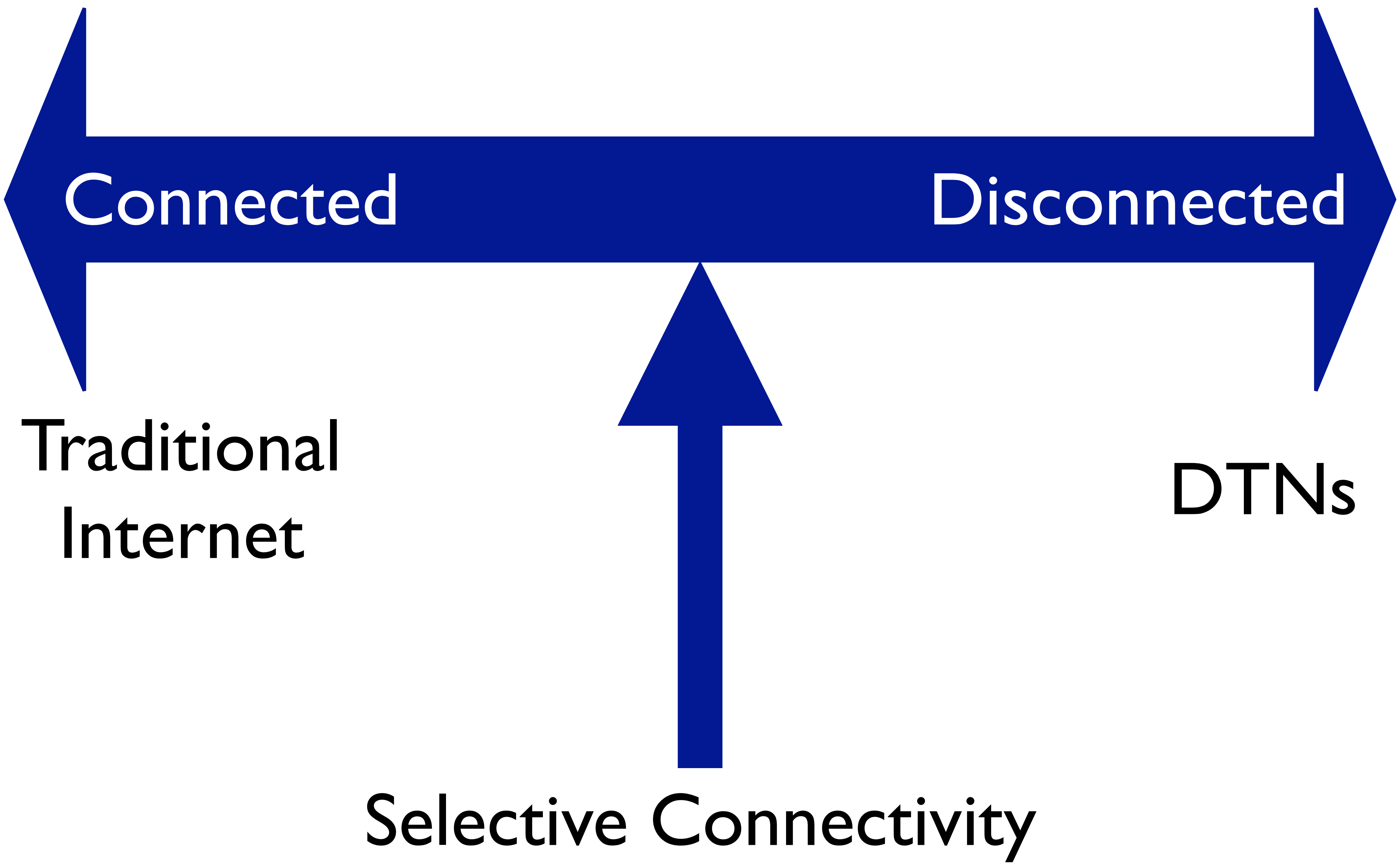
- Our architecture assumes connected hosts
- Disconnectedness is dealt with as a problem

Related Work

- More energy-efficient hardware
- Disruption-tolerant networking
- One-off retrofits to today's protocols
- Tiered power usage in wireless devices

- We take an architectural approach to the problem

Selective Connectivity



Example

- Consider an IM client
- Helps powered-down hosts by re-connecting after a host returns from sleep
- Our goal: to enable reception of messages while machine is selectively connected
  - Perhaps even from a select set of "buddies"
  - I.e., while sleeping the machine retains its *standing* in the network

Network Chatter

- Naive approach: wake machine when engaged
- Problem: hosts are continuously engaged for various reasons
  - Some important
  - Some not

Network Chatter (cont.)

- Computer not previously engaged in the network receives 6 pps over a 12+ hour period on a campus network [7]
  - Over 20 network protocols detected

Network Chatter (cont.)

- Assess "chatter" on internal LBNL networks
- Take a 60 second slice starting at 3:18 AM from each of the 72 traces in our collection
  - 4.49 pps on average (across traces)
  - Various types: backup traffic, Windows services, NFS, NTP, DHCP, SSH

Network Chatter (cont.)

- How much of this chatter reflects communication with a fully powered machine?

- We look for two-way flows
  - Based on MAC address

- 66 of our 72 slices include two-way flows
  - Median of 3 two-way flows per trace

Architecture

- Initial set of new architectural components / concepts
  - Could be wrong
  - Surely incomplete

Assistants

- Perform routine and mundane operations on hosts' behalf
  - Keep state alive by responding to keep-alives
  - Vet incoming traffic to allow only "important" activity to wake a host
  - Inform remote hosts to "re-try"

Exposing State

- Expose the level of connectivity across protocol stack and possibly to peers
- E.g., exposing a host's reason for being selectively connected might enable peer to also move to a reduced-energy state
- Tussle: exposing energy state may expose too much information

Evolving Soft State

- Soft state is one of the architectural successes of the Internet
- Maintaining soft state across selectively connected hosts poses a problem
- Two possible approaches:
    - *Proxyable State:* maintenance of state by assistant
    - *Limbo State:* recognition of distinction between “inexplicably gone” and “asleep”

Host-based Control

- We want to leave how selectively connected hosts are seen by others as a *policy decision*
  - E.g., what is exposed to which peers
  - E.g., what tasks are delegated
  - E.g., what events should wake the host

Application Primitives

- Could we design general application primitives to aid selective connectivity?
  - E.g., a generalized keep-alive that goes beyond a binary answer
  - E.g., a way to share a list of files the host makes available on a p2p network

- Perhaps there are not a set of primitives, but we would need to provide a *program* that encodes our needed functionality to an assistant

Security

- Security issues cut across our thinking
- Many questions:
  - How can tasks be securely delegated?
  - How does a peer know an assistant has authority to act on behalf of a host or app?
  - How do we layer our use of crypto to expose information needed by an assistant without exposing sensitive data?

Final Thoughts

- We are early in our thinking of the issues
- We likely don't have all the right models
  - That's why we're here!
- While energy savings has been our driver we think the resulting components could well be useful in other contexts
  - E.g., mobile hosts

Questions? Comments?