Networking Research in Digital Technology Center

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Outline

- Networking Trends
- Research Challenges
- What We’re Doing in DTC
  - project highlights
Networking Trends

Internet is the network!

- It’s big!
- It’s diverse!
- It’s complex!
- It’s everywhere (almost)!
- … and it keeps growing and changing!
Internet Growth
measured by number of Autonomous Systems (ASes)

AS: separately administered network domain

Source: Geoff Huston, http://bgp.potaroo.net
What Has Become of Internet

- Cyberspace and Virtual Communities
  - keep in touch with friends and strangers
- Information Service Platform
  - deliver all kinds of information
- Global Information Repository
  - store and search for all kinds of information
- Enormous Super-Computer
  - process information ("grid computing")

... we increasingly depend on it!
More gadgets are plugged in …

- servers, desktops, laptops, …
- PDAs, cell phones, blackberries, …
- *soon toasters, fridges, … 😊*

Wireless technologies revolutionizing Internet!
- WiFi, bluetooth, 3/4G cellular networks, …

High-tier

Low-tier

Wide Area

Local Area

High Mobility

Low Mobility

pervasive computing

smart space

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Diverging Trends ...

- **Internet Core: concentration**
  - high bandwidth, dense connectivity
  - data centers: computing, storage, ...

- **Internet Edges: diversification**
  - “smart” to “dumb” devices
    - PCs with increasing processing and storage capacities
    - small devices with limited computing, memory, power, ...
  - broadband to narrowband
  - “always on” to intermittent connectivity

**Challenges and Opportunities!**
- overcome heterogeneity, seamlessly integrate
- new services & “disruptive” technologies
New (& Old) Research Challenges

Well, networking is like plumbing ... nothing really glorious!

- making services highly available and reliable
  - "always on" Internet, no broken pipes, ...
- providing quality of service for applications
  - fast and fat pipes, specialized pipes, ...
- in particular, making Internet secure
  - protect pipes against malicious users

Internet: critical global information infrastructure, big, complex, massively distributed, and changing!
It’s All About Services!

Beyond bit pipes!

- Facilitating and enabling creation, deployment & delivery of services
  - existing, emerging and yet to be imagined
- Tapping and realizing potentials of new technologies
  - wireless technologies, sensor technologies
  - harness & leverage “disruptive” technologies
- Is current Internet architecture adequate?
  - what are limitations?
  - how to enhance and evolve Internet (incrementally)?
- New Internet architecture(s) for service overlays, pervasive computing, smart space, ......?
It’s Economy, Stupid!

Lesson from burst of “Internet bubble”

- Users:
  - technology adoption depends on users
  - providing values to users
    - useful, enjoyable, make life easier, ……

- Service providers:
  - generate revenues and reduce costs: capex, opex, etc.
  - viable business models: competitive nature of marketplace

Internet research & development needs to consciously take economic factors into account

- stagnation & ossification vs. sustained growth
Networking Research in DTC

Some Project Highlights

- **FILAR**: Failure Insensitive Load Adaptive Routing
  - making individual networks highly available and resilient
- Enhancing BGP (Border Gateway Protocol)
  - making Internet as a whole more stable and robust
- Secure Name Service (SNS)
  - protecting critical information services and resources
- **SOI**: Service-Oriented Internet Architecture
  - unifying service overlay substrate for service delivery
- Internet Economics
- **Pie**: (smart) Personal information environment
Why Failure Matters?

- Failures occur frequently in networks
  - faulty interface, flaky links, router crashes, fiber cuts, ...
  - mostly transient, last seconds to minutes
    - OC48 link down for 6 seconds: 3 million packets may be lost!

- Existing Approaches
  - Traditional routing protocols (OSPF/ISIS)
    - react to failures, slow convergence time
  - MPLS-based solutions
    - centralized, a lot of configuration, not adaptive
  - Packet delayed/lost during failure recovery phase
    - bad for Voice over IP (VoIP) & other emerging applications
FILAR for High Service Availability

- **FILAR**: nearly 100% forwarding continuity
  - prepare for (instead of react to) failures
  - adapt to changes while ensuring stability

- **Key Ideas**
  - local failure inference
  - local rerouting
  - interface-specific forwarding

- **Other Advantages**:
  - no change to forwarding plane
  - minimal change to routing plane

- In collaboration with Sprint (& Cisco)
BGP and Internet: A Quick Primer

- Internet comprised of many Autonomous Systems (ASes)
- BGP is the routing protocol gluing Internet together
  - announce network reachability to outside world
  - propagate routes learned to neighbors ("path vectors")
  - policy-driven: selectively accept/tell what are learned

- Issues with BGP:
  - Local failures/changes have global ripple effects
  - Long convergence time
    - can take up to 15 min
  - Inadequate in supporting many operational/service needs
    - traffic engineering, reliability,...
Enhancing BGP for Global Stability

- Analyzing global BGP behavior and dynamics
  - from UMN (thanks to NTS) and other vantage points
- Limiting BGP path exploration problem
  - fast invalidation of “obsolete” routes
  - embed “path dependency” using sequence numbers
- Dampening route flaps
  - effectively identify route flaps
  - localize instability
- Codifying routing policies
  - minimize misconfiguration
- “Shadow” control plane
  - policy consistency check
  - diagnostics
Secure Name Service

- Protecting critical information services and resources
  - front-end and back-end servers, databases, ... 
  - prevent unauthorized accesses and denial-of-service attacks

- Extension of Domain Name Service (DNS)
  - place critical services and resources in secure name zones
  - virtualize resources, conceal IP addresses from outside
  - establish explicit trust relations among trusted domains

- Key Components:
  - Domain-level trust management (domain trust managers)
    - key exchange among domains, users always authenticated
  - Secure name resolution (secure name servers)
    - secure name query returns “secure handle,” not IP address
  - Secure packet forwarding (security checkpoints & gateways)
    - packets carry “security tags”, authenticated at entry points

  protect, monitor and counter-act
Secure Name Service Operations

TTP : Trusted Third Party
TM : Trust Manager
SNS : Secure Name Server
SC : Security Checkpoint
SG : Security Gateway

Domain 1
Zone A
SNS1
TM1
host1
SG1
SC1

Domain 2
Zone B
SNS2
TM2
SG2
server

TTP to Domain 1 via TM1
TTP to Domain 2 via TM2

Attack traffic filtered out
SOI: Service-Oriented Internet

- Beyond network connectivity
  - current IP infrastructure: host-to-host connectivity
- Facilitating service deployment and service delivery
  - rapid service creation and deployment
  - high service availability, reliability, QoS, security, ...
  - flexible built-in support for economic incentives
- Key Abstractions:
  - service clouds: (“application service provider networks”)
  - new two-level location-independent addressing scheme:
    - service id identifying a service cloud
    - object id identifying an entity within a service cloud
  - service layer:
    - unifying service overlay substrate, built on top of IP
SOI Architecture Illustration

service cloud A

users
servers

service points of presence
service gateways

common service gateway sublayer

service-specific delivery sublayer

network domain 1

routers

network domain 2
Internet Economics

In collaboration with Andrew Odlyzko

- Internet Evolution and Impact of Economics
  - Business relations between ASes
    - peering, transit (customer-provider), etc.
  - How they shape Internet structure and evolution
- New Business Models for Service Deployment & Delivery
  - Service models: billing, settlement, etc.
  - Cost/benefit analysis, e.g.,
    - economic efficacy of IP multicast and proper settlement model
    - business models for overlay services
- Mechanisms and Architectures:
  - How to enable new services and meet their requirements
Pie: (smart) Personal Info Environment

- Bottom-up approach to (eventually) build smart space
  - start with personal info and computing resources
  - integrate, simplify and make life easier for individuals
  - extend to groups, communities and so forth later
- A Simple Example: LIVIDO
  -- Location Independent Virtual Internet Document Organizer
  - organize documents virtually across platforms, across file systems
  - auto-synchronization, version control, backup, etc.
  - an undergraduate directed research project
- Pie: extending LIVIDO to other info & resource mgmt
  - personalized name and directory services
  - personalized event handler and notification
  - remote execution, context-aware computing
Networking Faculty in DTC

- "Core" Networking Faculty
  - David Du (networking, multimedia, storage)
  - Zhi-Li Zhang (networking, multimedia, middleware)
  - Yongdae Kim (security)
  - Andrew Odlyzko (Internet economics)

- Will have more soon!
  - ADC/Qwest chairs, CSE new networking faculty

- Others doing research related to networking:
  - Jaideep Srivastavara, Anand Tripathi, Jon Weissman,
    ......

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Networking Research: Zhi-Li Zhang
Funding and Collaboration

- Multi-Million $$ from Gov. Funding Agencies
  - National Science Foundation
- Active Collaboration with Industry
  - Sprint
  - CISCO
  - IBM
  - Honeywell
  - ......
  - Industrial Research Partners Always Welcome!
- More than a dozen Ph.D students, plus many more MS and undergrads involved in networking research
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Thank You!
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Questions?
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Project Highlighted

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- Internet Economics
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URL: http://www.cs.umn.edu/research/networking