Active Networks

"Towards an Active Network Architecture,"
D. Tennenhouse, D. Wetherall, CCR 1996

Winner of ACM SIGCOMM 2007 "Test-of-Time Award"

Internet in 1996: Routers are passive -- just move bits around

Bits are either dropped or delivered unaltered

Routers is a close platform. Only vendors can modify functionality at routers

Hard to deploy new services

Example:

IPv6
IP Multicast
RED

Internet evolves slowly compared to PC and Web

Web and PC florishes because anyone can easily deploy new application and services (they're programmable!)

Two more examples:

Facebook
Second Life

Idea: Let's make the Internet programmable

Users can insert code into the network and run computations on packets

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1. Cisco etc.
2. Authorized Vendors
3. End users

Users can **insert** code into the network and run computations on packets

1. install program onto router
2. packet carries program

Users can insert **code** into the network and run computations on packets

1. program/function name
2. scripts
3. binaries

Users can insert code **into the network** and run computations on packets

1. special, "active nodes"
2. any routers

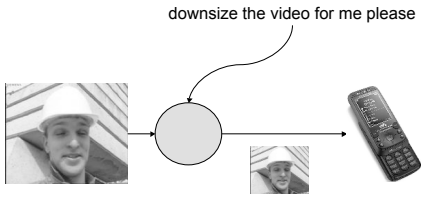
Users can insert code into the network and **run computations** on packets

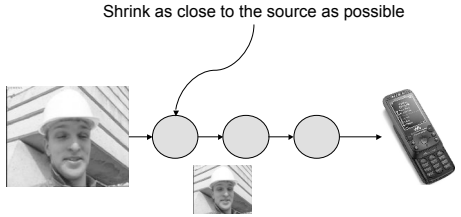
1. network (eg: routing)
2. transport (eg: packet filtering)
3. application (eg: compression)

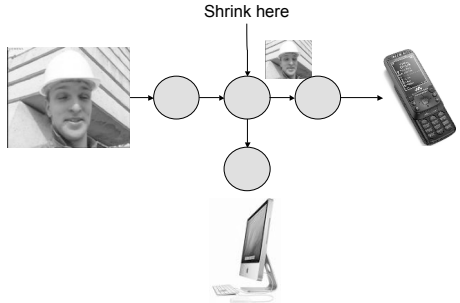
Examples of Services in Network

Authorized application vendors can program firewall to let their packets through

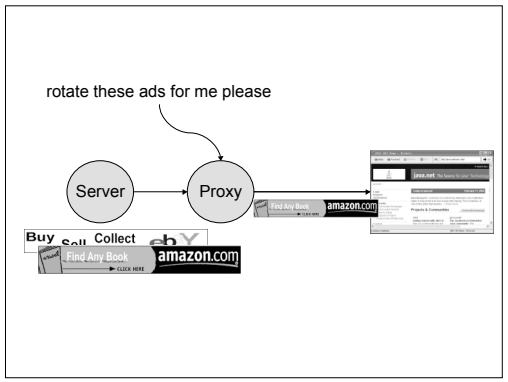
Users can adapt video to fit their bandwidth/screen-size



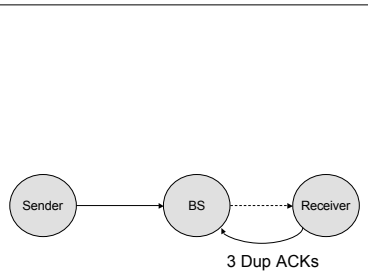


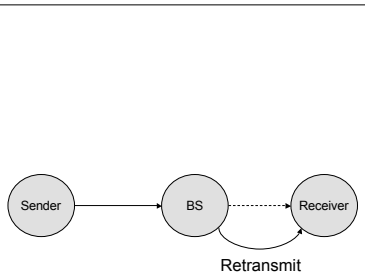


Web caches can generate dynamic web pages



Wireless base station can retransmit packets





Approaches to Active Network

Two Approaches to Active Network

1. Discrete
2. Integrated

Discrete Approach

Packets are send normally, but header identifies additional function to operate on the packet (possible changing it)

Integrated Approach

Packets carry code with them, code gets executed from node to node

Capsules = "Packets that carry code (and maybe data)"

Examples

```
ack()  { print "ok"}
ping(src, dest) {
  if this is dest
     eval(src, ack())
  else
     eval(dest, ping(src,dest))
}
```

```
ack(x)  { print x}
traceroute(src, dest, x) {
  if this is dest
     eval(src, ack(x))
  else
     next = getNextHop()
     eval(next, traceroute(src,dest,x+1))
}
```

Execution Environment for Capsules

Issue: need to restrict the capability of capsules

(e.g. my capsules shouldn't delete your capsules, or change the routing tables of other capsules)

Issue: need to limit the resources used by capsules

(e.g. a capsule that goes into infinite loop should not hang the router, or should not replicate itself infinitely)

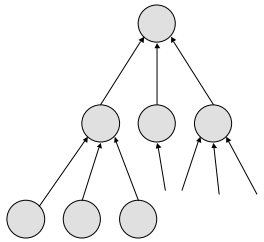
Issue: capsules need to be executed on a variety of platforms

We know how to do this using virtual machines and sandboxes (e.g. java applets)

Router provides basic API to access routing tables, links information
(e.g. getNextHop())

Capsules may leave states behind in the executing environment

Example: in informaion fusion applications



Example: roll call -- find out how many multicast receivers are there

```
var total = 0, count = #children
call( )  {
  if no children eval(parent, reply(1))
  for each child c
     eval(c, call())
}
reply(x) {
   total += x; count --
   if (count is 0) eval(parent, reply(total))
}
```

Will need to support garbage collection of states and execution environment

Active Network and E2E Arguments

E2E Argument

"The function in question can completely and correctly be implemented only with the knowledge and help of the application standing at the endpoints of the communication system. Therefore, providing the questioned function as a feature of the communication system itself is not possible. (Sometimes an incomplete version of the function provided by the communication system may be useful as a performance enhancement)"

Does Active Network violate E2E argument?

E2E is more about which layer to implement a function, not which node

Previously,
app/transport layer = end hosts
network layer = routers

Distinction is not as clear with active networks

How to choose end-point?

The end-point is a trustworthy entity.

In Active Network, we should trust our own code, regardless of where it is executed.

Implementation and Performance

ANTS: Active Network Implementation from MIT

Java based Implementation

Code are hashed using one-way function (MD5)

Capsule include a 128bit hash that identifies which code to run

Security Implications:

can't change the code (hash will be inconsistent)

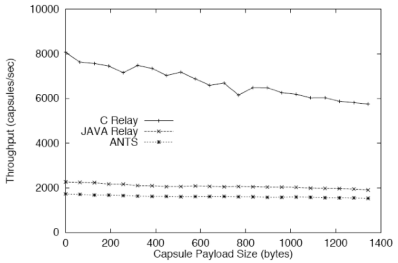
can't guess the hash without knowing the code

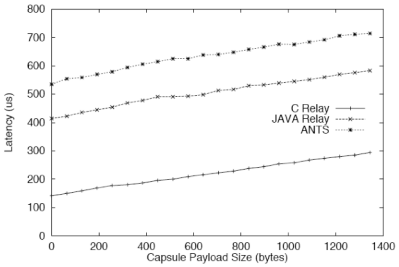
Code needs to be signed and certified by a trusted authority, then posted online for others to use

Code can be cached each node. If a code needed by a capsule is not available, ask from the node upstream (where the capsule came from)

To bootstrap the process, the code is install in the "local" active node (e.g. NUS gateway)

Code size is limited to 16KB to avoid distributing large amount of code





Can process up to 1.5Mbps (T1 link)

100Mbps possible with in-kernel, native implementation (but less protection)

Historical Perspective

Initiated a flurry of research activities and debates between 96-00

Main Criticisms

"Killer App"?
Performance + Security?

An example of research that involves:

OS, PL, Networking, Security, DS

Still (somewhat?) relevant today: network no longer just forward packets

NAT
WAN accelerator
SIP gateway

NAT
WAN accelerator
SIP gateway

Also relevant in wireless sensor networks for deploying new services onto sensor fields