Making Paths Explicit in the Scout Operating System

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Outline

1. Motivation
2. Path Architecture
3. Scout Example
4. Conclusions

Network Appliances

- Network Devices
  - cameras
  - disks
- Smart Cards
- Set-top Boxes
- Multimedia Stations
- Scalable Server Nodes

Note: Network appliance is more than just a fancy name for computers. There are some distinctive properties...

NA Characteristics

- Communication-oriented
- Specialized functionality
- Diverse functionality
- Predictable performance
- Scarce resources

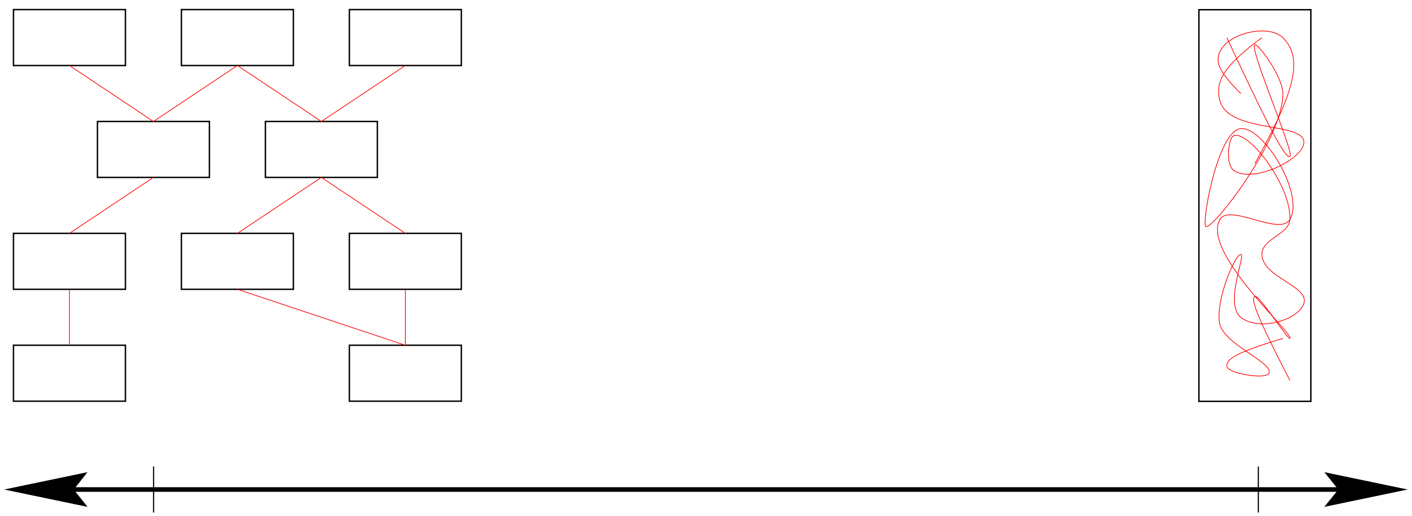
Don't abbreviate Network Appliance during speech!!

Diverse functionality often causes creeping generalizations (bad OS designer habit).

Predictable: reliable and realtime (to some degree)

NA Software

Modular design: Vertical Integration:



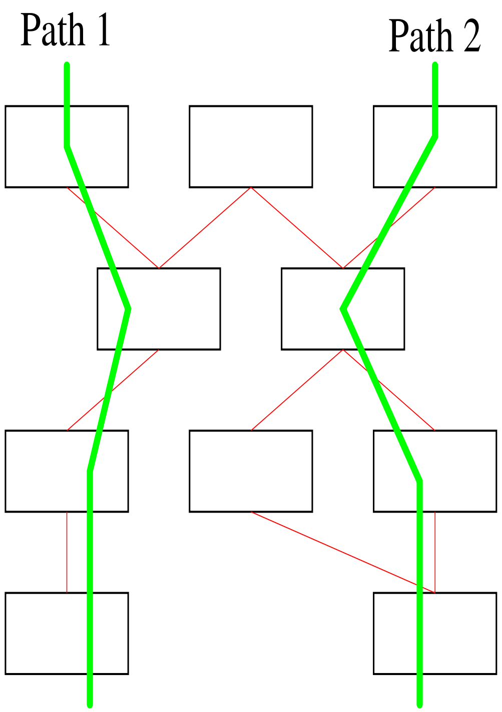
Flexible
Reusable modules
Performance suffers

Best performance
Complex
Expensive

Note: performance suffers since NAs are communication oriented. I.e., most time is not spent in a single module but divided across all the modules that the data crosses.

Paths: An Alternative Solution

- Modularity for:
  - flexibility
  - managing complexity
- Paths to solve problems requiring global context:
  - improve code quality
  - make better resource management decisions



Paths can be interpreted as a (mostly) automatic way to derive a vertically integrated system form a modular system.

Paths: Examples

- Synthesis [Massalin & Pu]: Specialize code for entire path
- Fbufs [Druschel & Peterson]: Fast data-transfer by knowing “domains” crossed
- ILP [Clark & Tennenhouse, Abbott]: Collapse data-processing of several layers
- Migrating Threads [AlphaOS, Spring, FLUX]: Improved accounting for thread crossing servers

Paths: Fundamental Idea

Expose and exploit non-local context...

...in a systematic manner and based on a modular system.

- Synthesis: Know *all* the code and runtime-constants.
- Fbufs: Know the set of "domains" crossed early and at any point in time.
- ILP: Know the sequence of data manipulations.
- Migrating threads: At any point, know who to "charge."

Need to say something about elevating paths from an ad-hoc solution to a fundamental OS abstraction.

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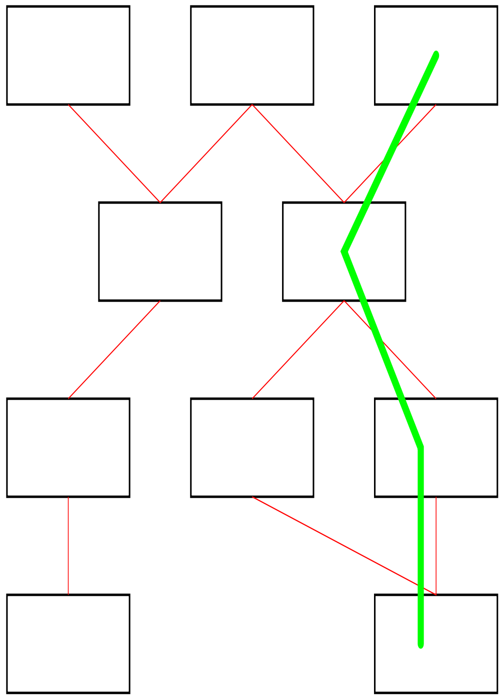
Path Architecture

- Router Graph
  - defined at build time
- Invariants
  - specified at open time
- Path
  - sequence of fixed routing decisions



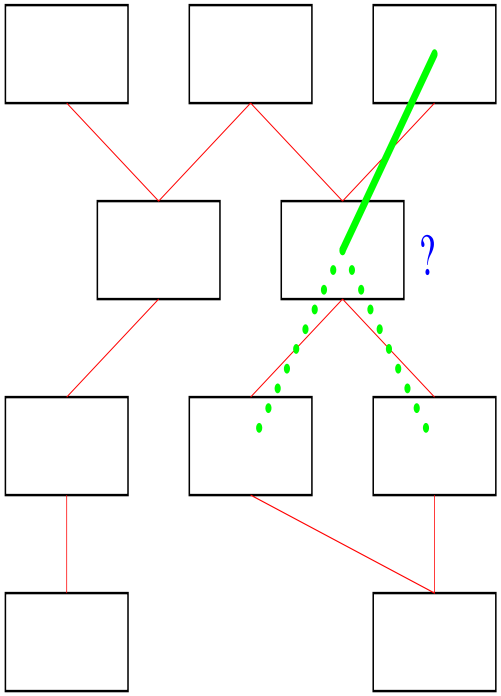
Transition: Now to the fine print (sequence of problems that make this hard).

Path Creation

$p \leftarrow$ `pathCreate`$(router,\ invariants)$:

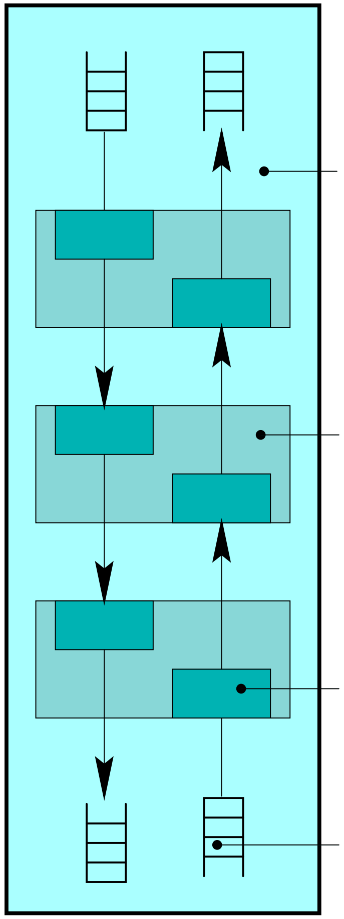
1. Create incrementally:
   Each router makes (local) routing decision, then forwards request.

2. Optimize globally:
   Apply path transformations that match created path.



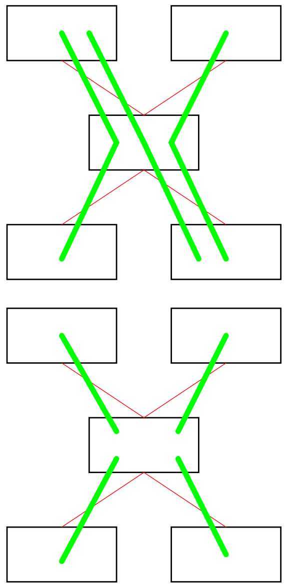
Path Object

- Each router contributes a stage
- Interfaces to move data through path
- Queues to decouple scheduling



How to Use Paths

- Wide vs. narrow
  - per data item
  - per connection
- Long vs. short
  - Long for best optimization
  - Short for generality or minimum memory usage



⇒ path architecture must be policy-free

Mention “dynamic routing decision” with the “generality” bullet.

Path Execution

- Threads:
  - Created by routers
  - First-class objects
- Path execution:
  - Router assigns thread to initiate execution of one of its paths
  - Thread inherits scheduling parameters from path
  - Same thread can cross several paths

Finding Paths

- Usually obvious
  - e.g., file descriptor, window handle, ...
- Sometimes data-dependent (e.g., based on network headers):
  - Each router provides demux operation:

    $$(pset', next\text{-}router) \leftarrow \texttt{demux}(pset,\ msg)$$

  - If final $pset'$ contains exactly one path, deliver to that path, otherwise drop

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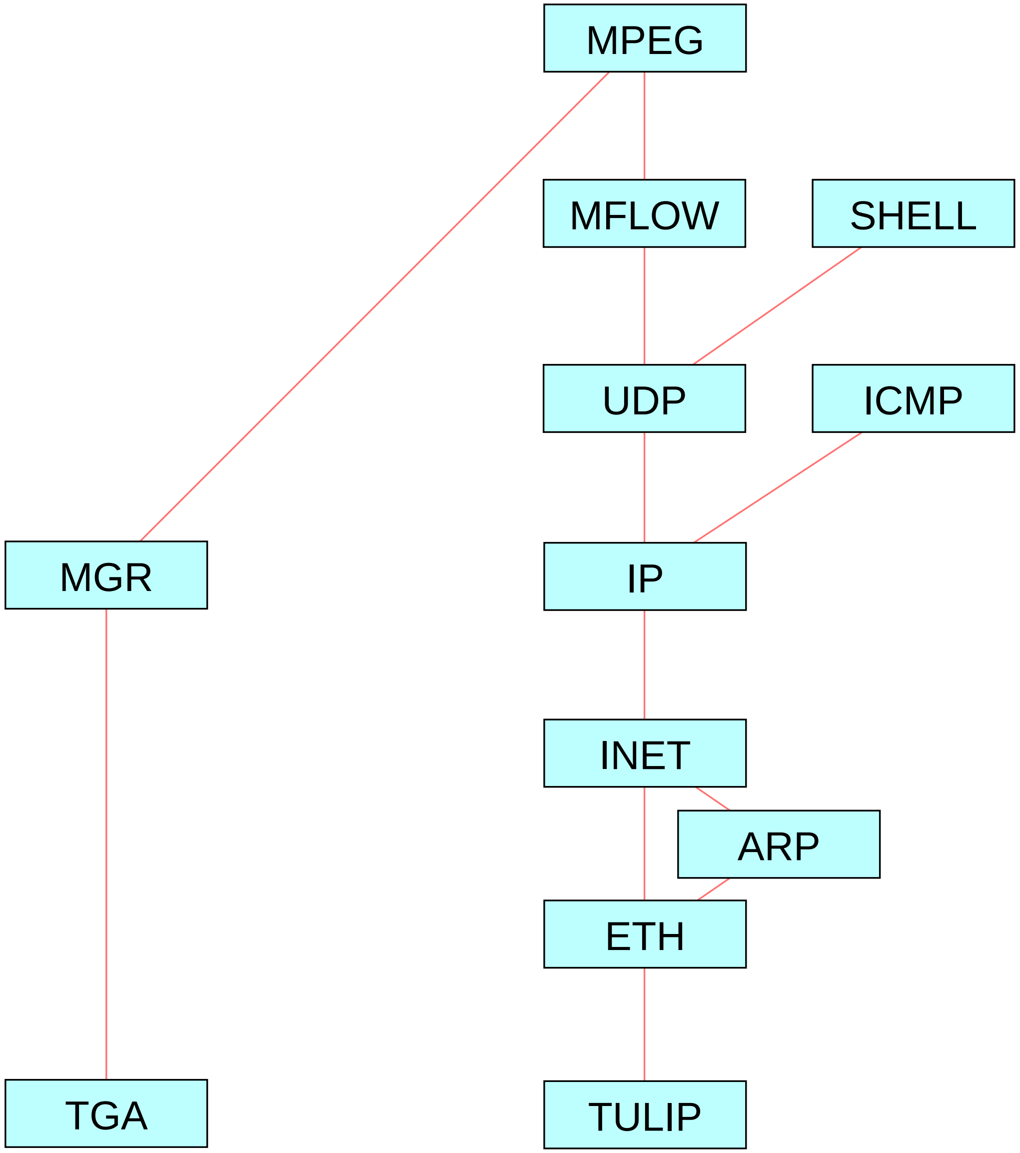
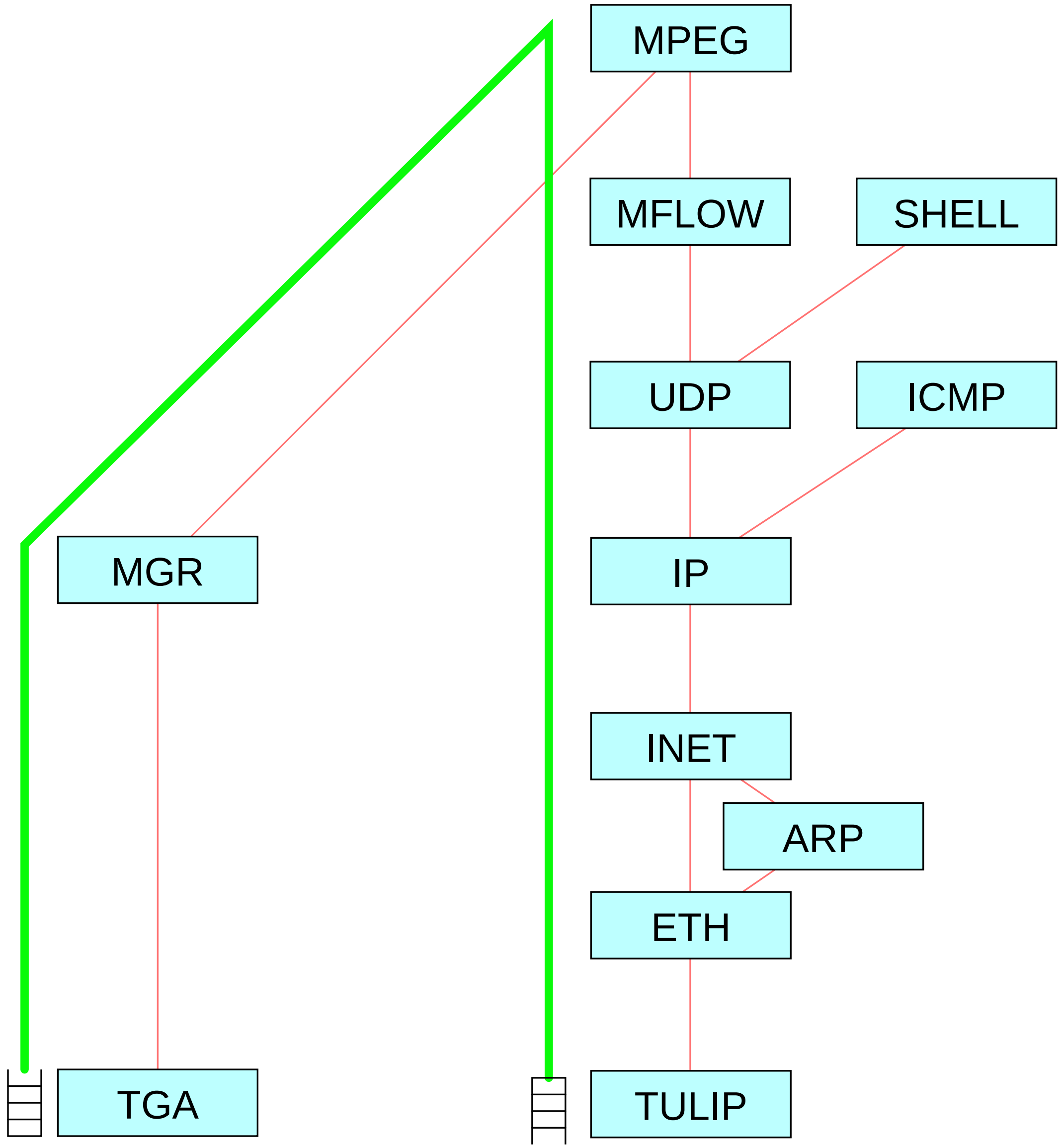
See paper and demo outside for more.

Scout MPEG Demo



- Scout: path-based OS, targeted at Network Appliances
- MPEG (tell me about picture)
- Problems due to lack of path

Scout MPEG Demo



- Explain with path:
  - Only one path shown, but can have many
  - Know in Ethernet driver whether packet belongs to MPEG vs. ICMP.
  - Can schedule entire processing according to bottleneck queue (input or output) and with appropriate policy (e.g., RR vs. EDF)

Resource Management Benefits

- Early segregation of work $\Rightarrow$ avoids priority inversion
- Schedule according to bottleneck queue
- Discard unnecessary work early
- Could use for admission control

Conclusions

- Defined path architecture
- Implemented Scout, a path-based OS, and demonstrated MPEG decoder
- Many questions need more research:
  - Resource scheduling & path policies
  - Applying paths outside of networking domain:
    - File systems [Hartman & Chiu]
    - Secure paths [Spatscheck]
    - Windowing systems [Khune]

- Global comment: With paths, we start to look at the system differently.

Scout Project Info

http://www.cs.arizona.edu/scout/

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