"Networking is IPC": A Guiding Principle to a Better Internet

Internet 1.0 is broken
Internet 2.0 is a repeat with more b/w
How about Internet 3.0?

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What this talk is (NOT) about

- NOT about specific protocols, algorithms, interfaces, implementation
  - about protocol structure, performance models
- It's about architecture, i.e., objects and how they relate to each other
- It's based on the IPC model, not a specific implementation

"Networking is inter-process communication"
--Robert Metcalfe '72

Talk Outline

- Problems with today's Internet architecture
- Our Recursive IPC-based Net Architecture
  - one IPC layer that repeats over different scopes
- One Data Transfer Protocol
  - soft-state (ala Delta-t) approach
- One Common Application Protocol
  - stateless, used by management applications
- Naming & addressing
  - multihoming, mobility
- Security, adoptability, conclusions

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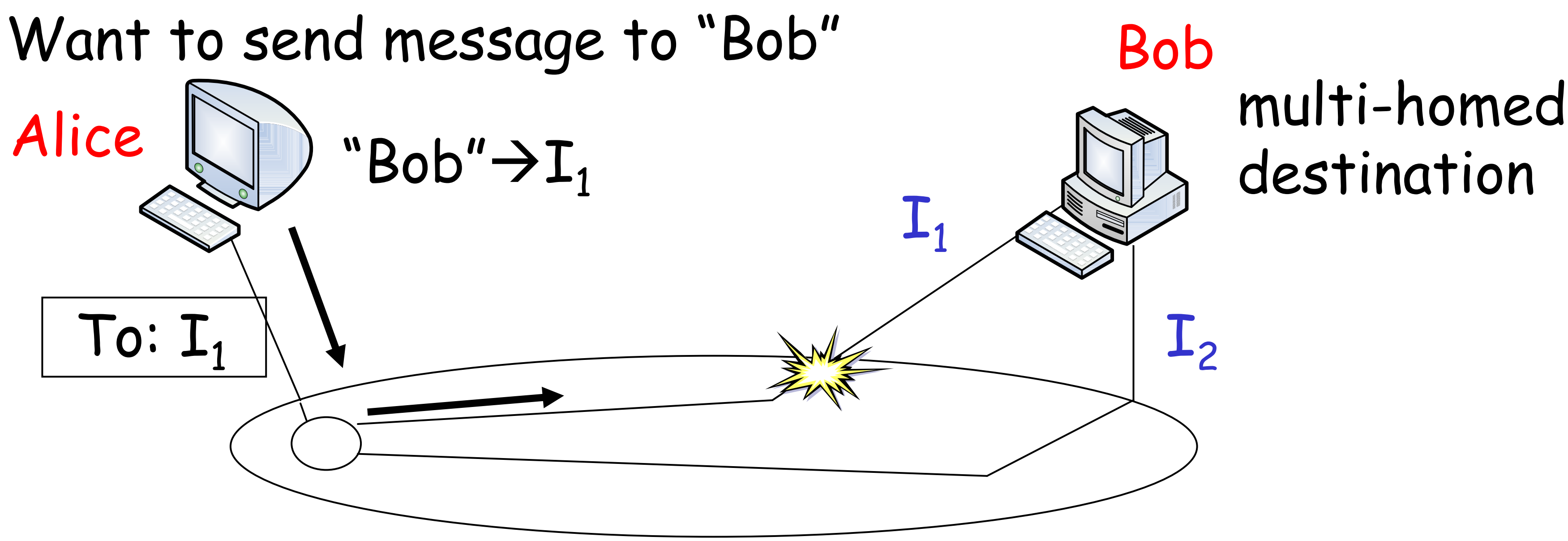
A Fundamentally Broken Architecture

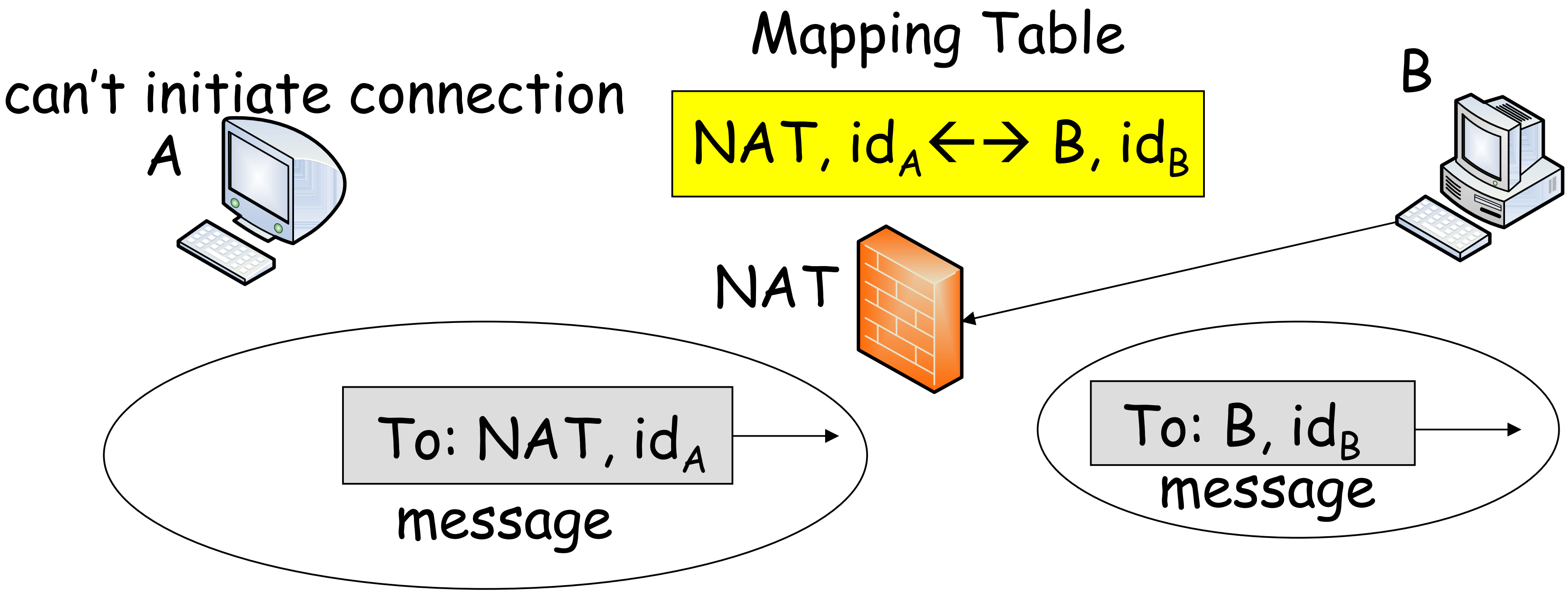
- Bunch of hacks
  - No or little "science"
- Lots of problems
  - Denial-of-service attacks, bad performance, hard to manage, …
- Why?
  - Too big, too flat, too open
  - We're seeing what happened with Wall Street…

Ex1: Bad Addressing & Routing



- Naming "interfaces" – i.e., binding objects to their attributes (Point-of-Attachment addresses) – makes it hard to deal with multihoming and mobility
- Destination application process identified by a well-known (static) port number

Ex2: Ad hoc Scalability & Security



- Network Address Translator aggregates private addresses
- NAT acts as firewall
  - preventing attacks on private addresses & ports
- But, hard to coordinate communication across domains when we want to

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Our Solution: divide-and-conquer

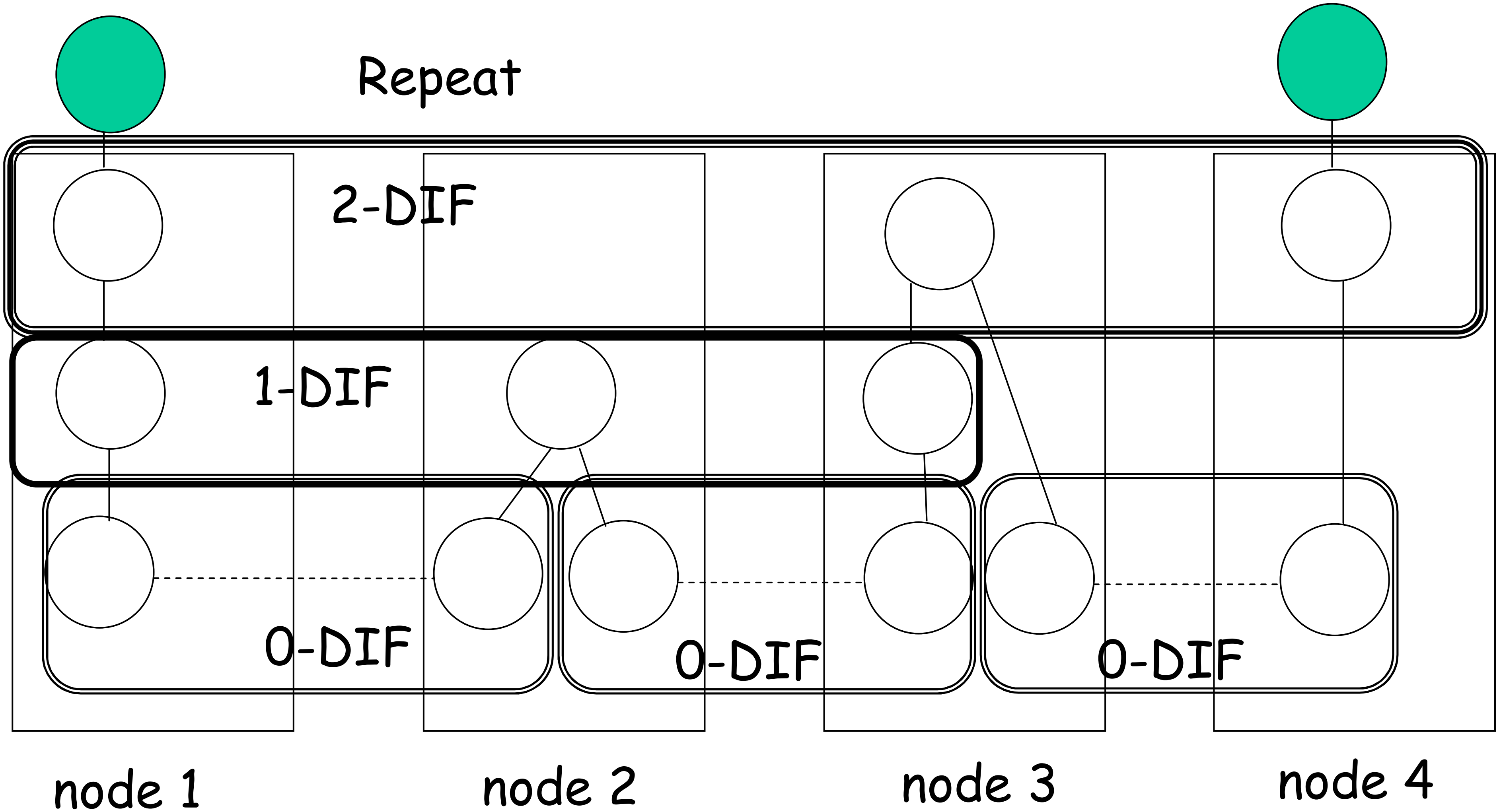
- Application processes communicate over IPC facility
- How IPC managed is hidden ➔ better security

- IPC processes are application processes of lower IPC facilities
- Recurse as needed

  ➔ better management & scalability

- Well-defined interfaces ➔ predictable service

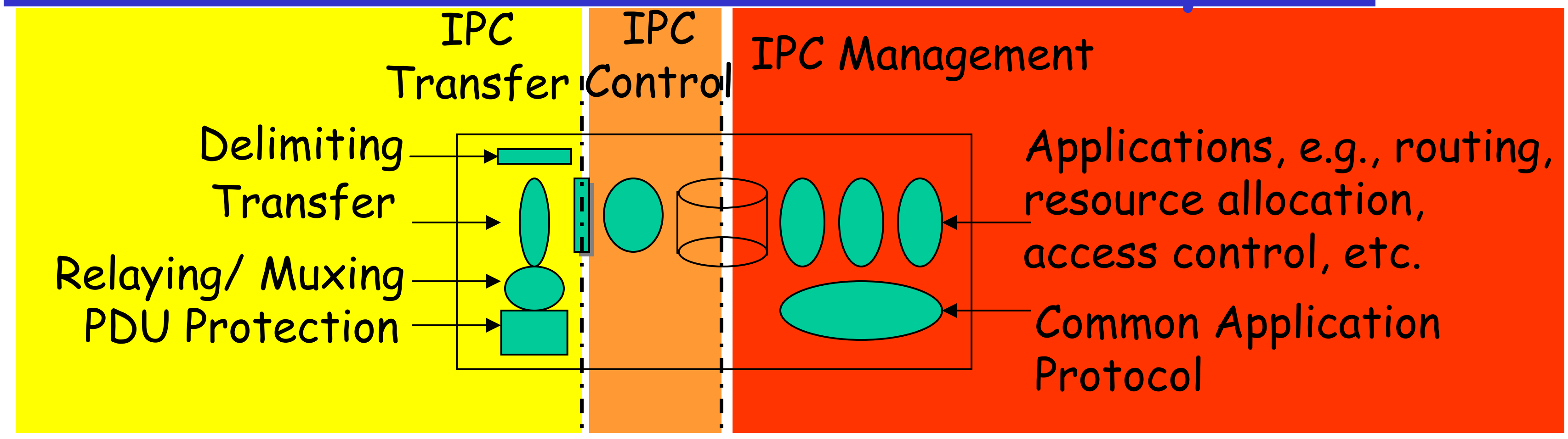
Architecture based on IPC



DIF = Distributed IPC Facility (locus of shared state=scope)

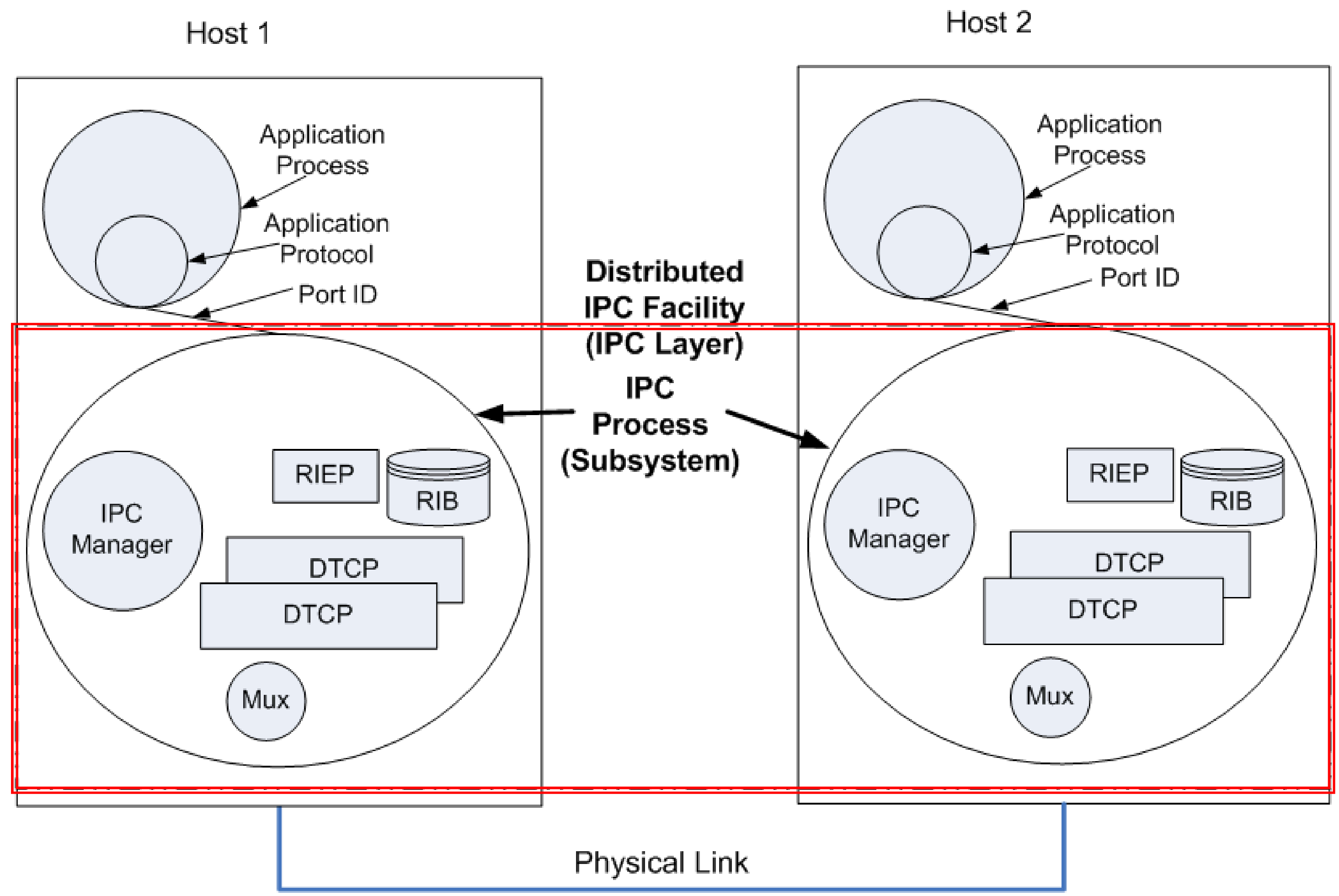
Policies are tailored to scope of DIF

What Goes into an IPC Layer?

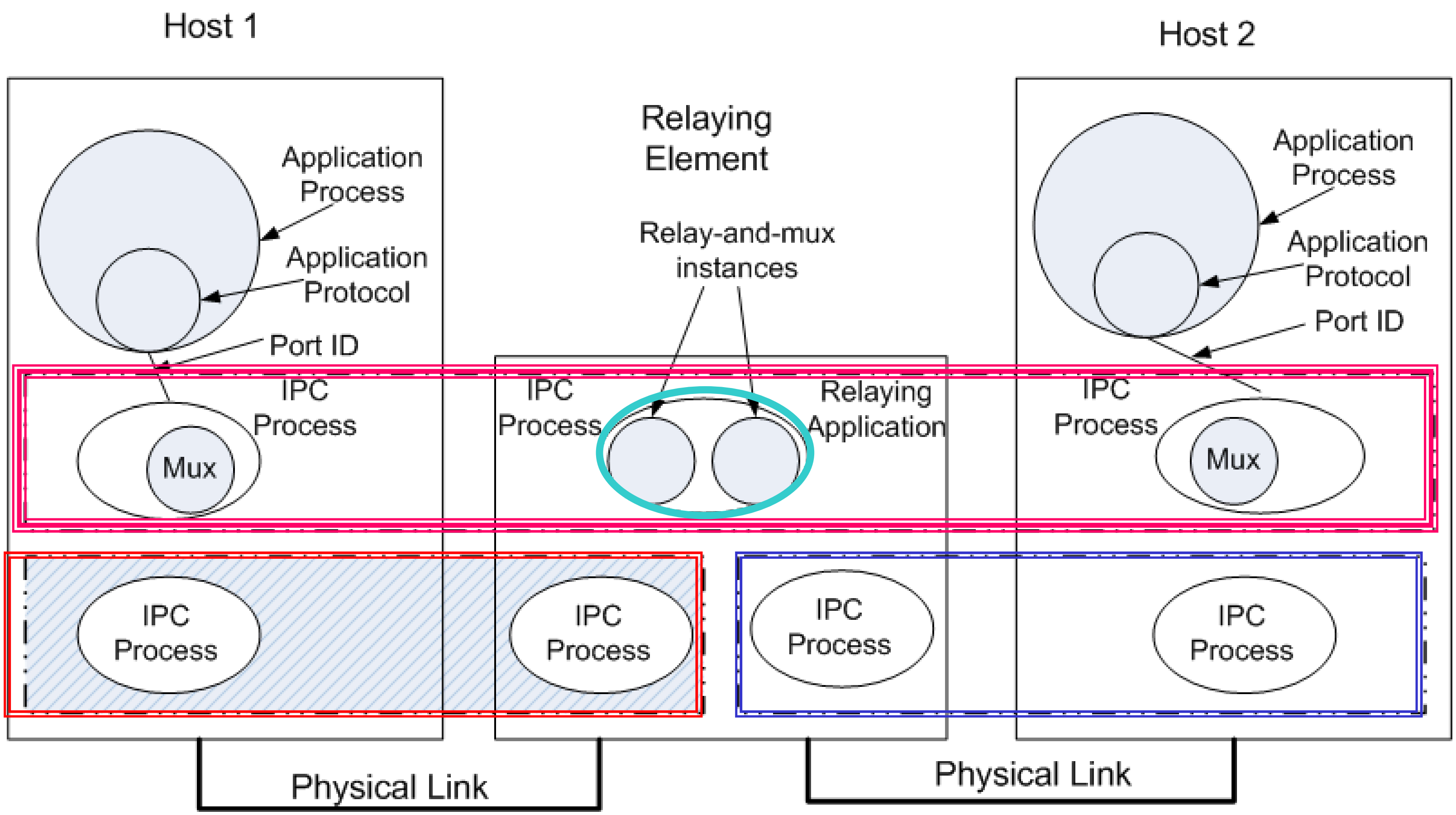


- Processing at 3 timescales, decoupled by either a State Vector or a Resource Information Base
  - IPC Transfer actually moves the data
  - IPC Control (optional) for error, flow control, etc.
  - IPC Management for routing, resource allocation, locating applications, access control, monitoring lower layer, etc.

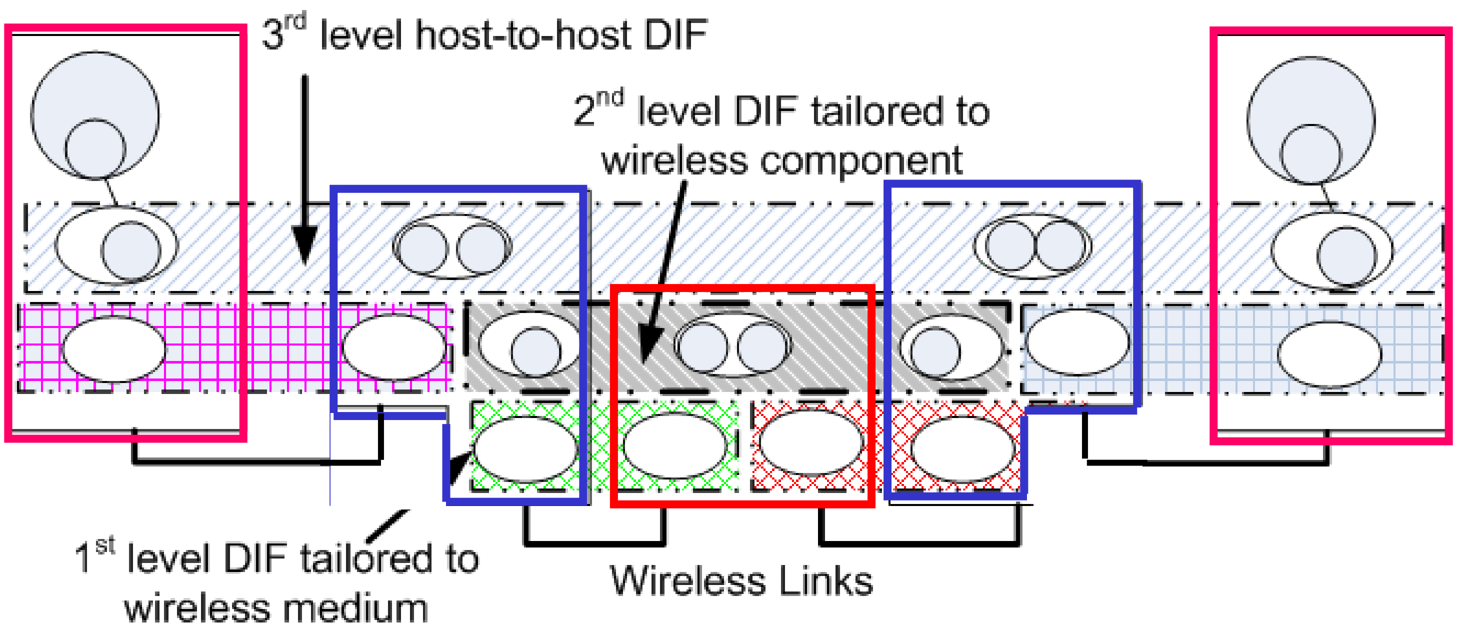
Two-system Case



Multi-system Case



Only 3 Kinds of Systems



- Host, internal router, border router
- No middleboxes, no NATs, ...

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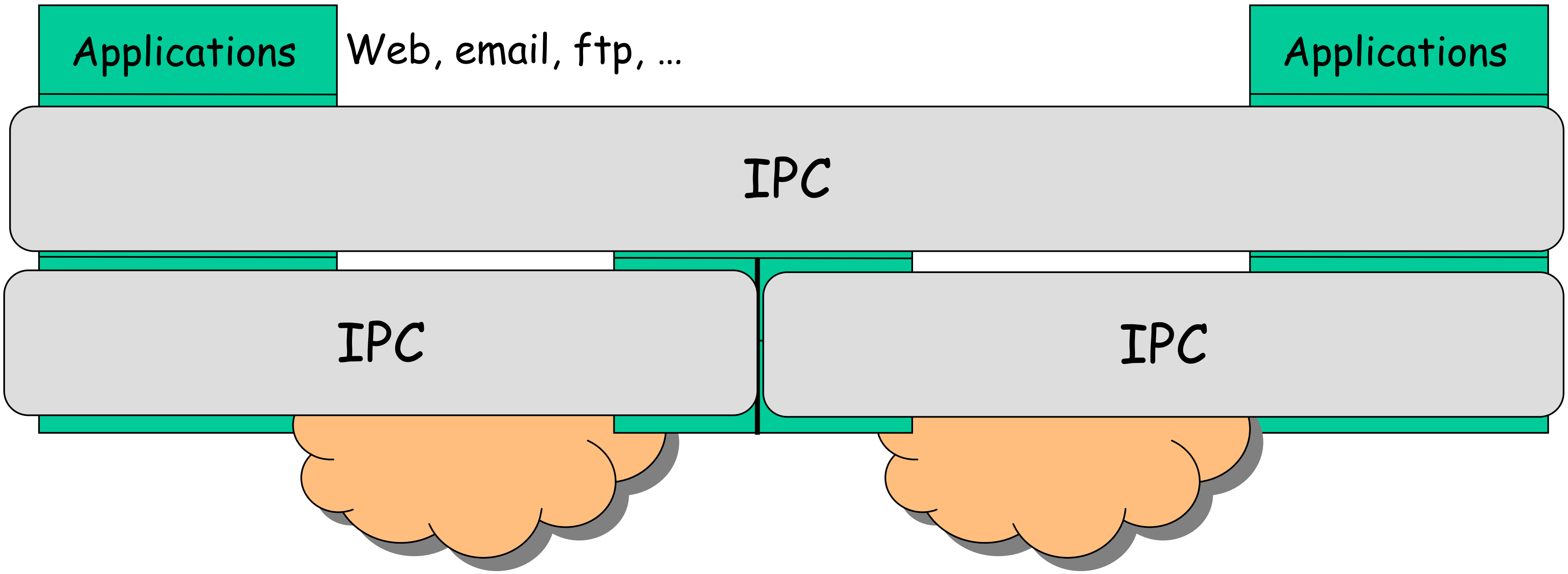
Compare to Current Stack (1)



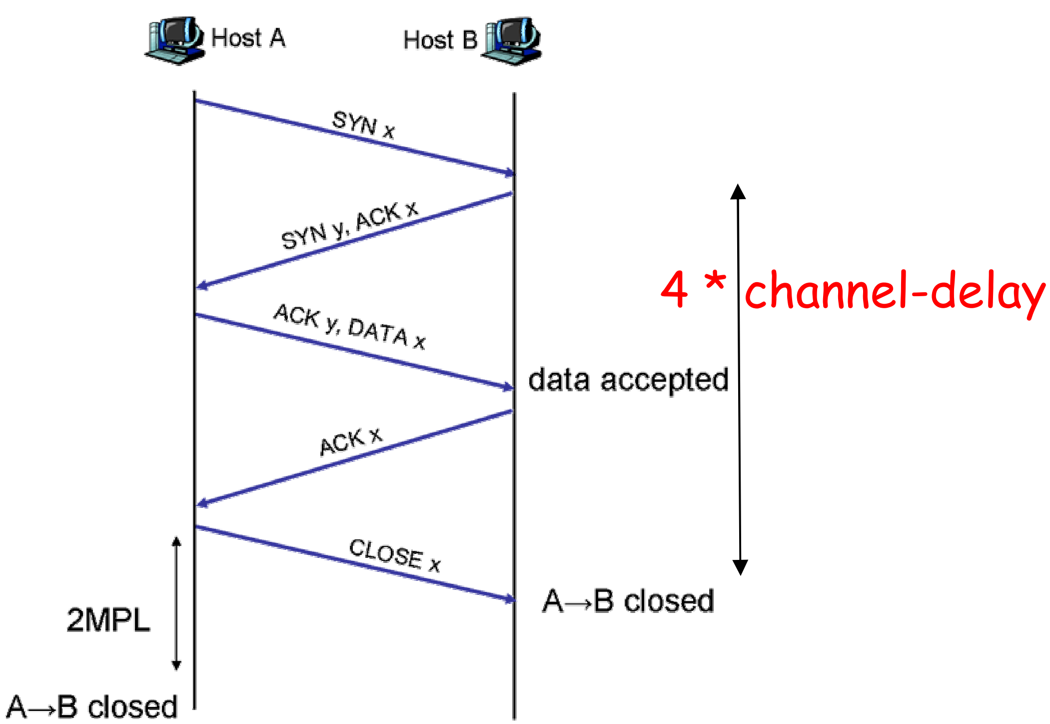
- Good we split TCP, but we split TCP in the wrong direction!
- We artificially isolated functions of same IPC / scope
- We artificially limited the number of layers / levels

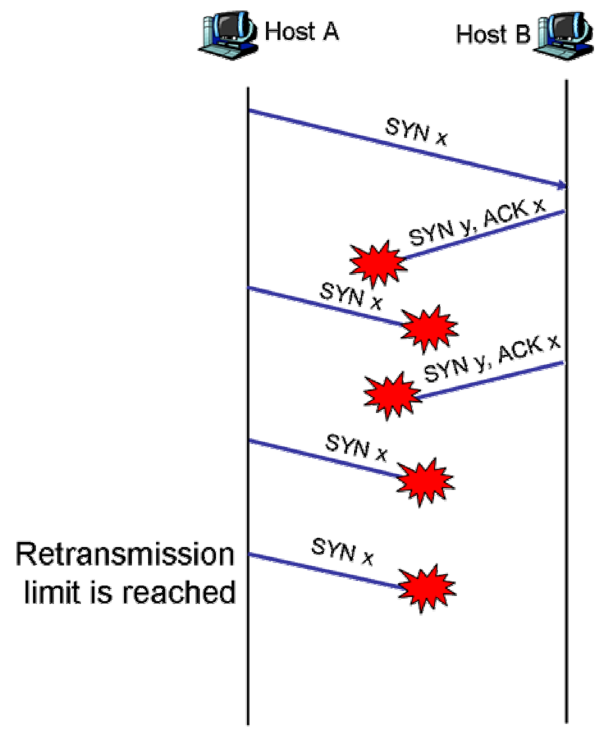
TCP was partly split to separate "hard-state" from "soft-state"

- Hard-state must be explicitly discarded
- But we don't need it to be [Watson '81]
- Watson proves that if 3 timers are bounded:
    - Maximum Packet Lifetime (MPL)
    - Maximum number of Retries (G)
    - Maximum time before Ack (UAT)
  - That no explicit state synchronization, i.e., hard-state, is necessary
    - SYNs, FINs are unnecessary
- In fact, TCP uses all these timers and more
- TCP is really hybrid HS+SS

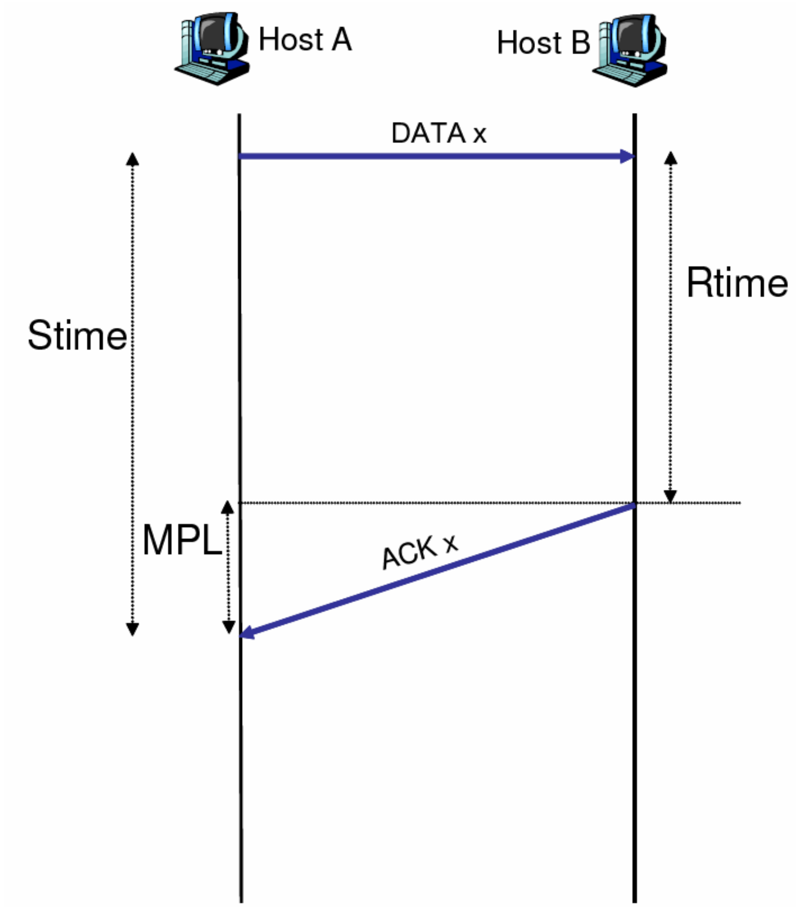
Five-Packet Protocol (ala TCP)

- Explicit handshaking: SYN and SYN+ACK messages
- For single-message communication, TCP uses five-packet protocol + timers (HS+SS)
- Vulnerability: Aborted connections ☹





Delta-t Protocol (Watson '81)



- A pure SS approach
- Two-Packet Protocol (Belsnes '76) with timers
  - Assumes all connections exist all the time
  - TCBs are simply caches of state of ones with recent activity
- G = n x RTO
- Rtime = 2MPL + G + UAT
- Stime = 3MPL + G + UAT

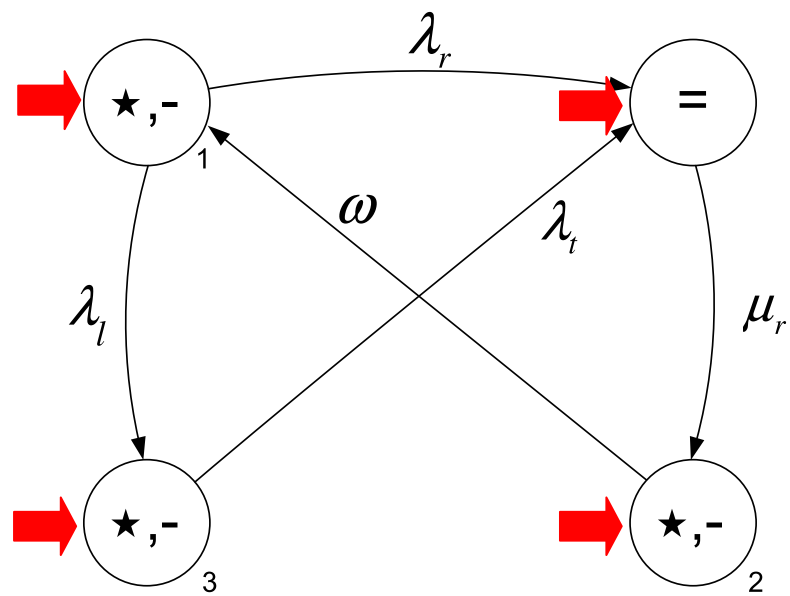
Rtime ~ 2 MPL > 4 channel-delay

Analytical Model

- Worst-case single-message communication
- Only the initial messages (with DATA) can get lost
- A new conn starts when previous one ends
- p: loss prob. D: channel delay

	Delta-t Protocol	Five-Packet (TCP) Protocol
λ_r	$(1-p)/D$	$(1-p)/D$
λ_l	p / D	p / D
λ_t	$(1-p)/RTO$	$(1-p)/RTO$
ω	$1/MPL$	$1/MPL$
μ_r	$1/Rtime$	$1/4D$

* : conn state installed at this end
- : conn state not yet installed
= : state installed at both ends



λ_r = arrival rate of initial message at the receiver

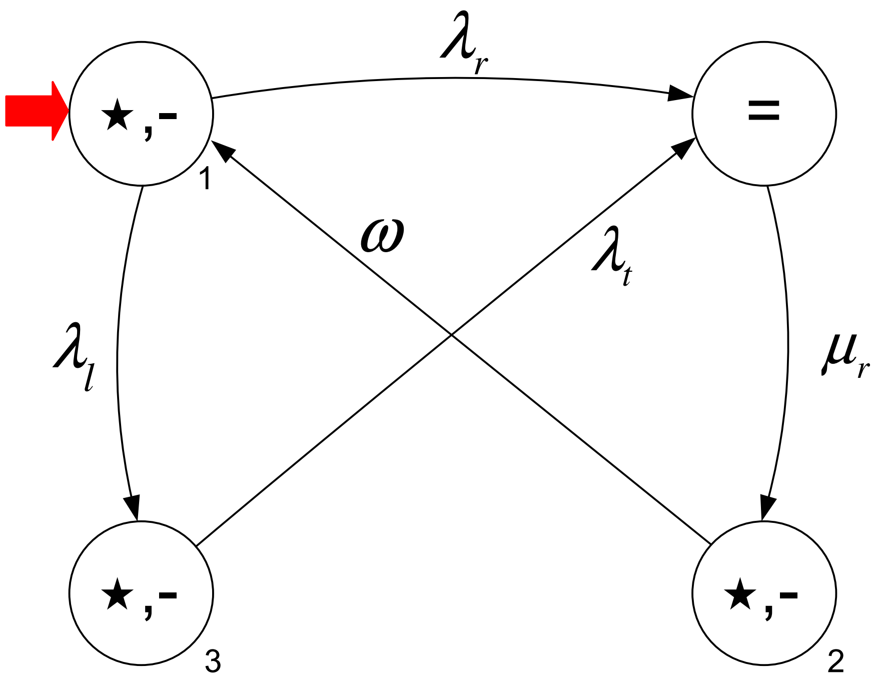
λ_l = loss rate of initial message

λ_t = successful retransmission rate of initial message

μ_r = connection state removal at the receiver

ω = connection state removal at the sender

Analytical Model



- Goodput

$$\upsilon = \pi_{(*,-)_1} / D$$

- Message Rate

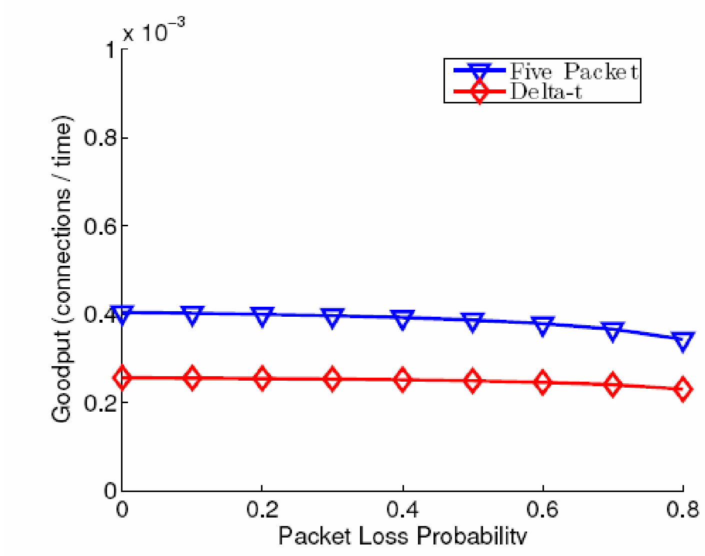
$$\varphi_{five} = \frac{1}{D}\pi_{(*,-)_1} + \frac{1}{RTO}\pi_{(*,-)_3} + \frac{1}{D}\pi_{=}$$

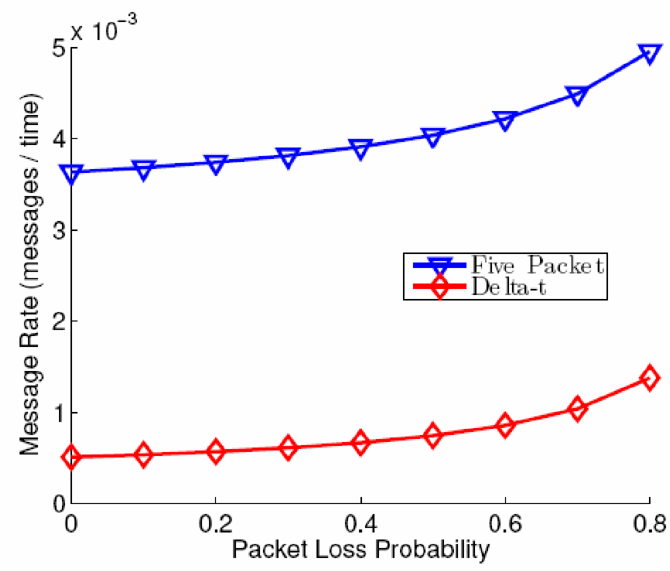
$$\varphi_{delta} = \frac{1}{D}\pi_{(*,-)_1} + \frac{1}{RTO}\pi_{(*,-)_3} + \frac{1}{Rtime}\pi_{=}$$

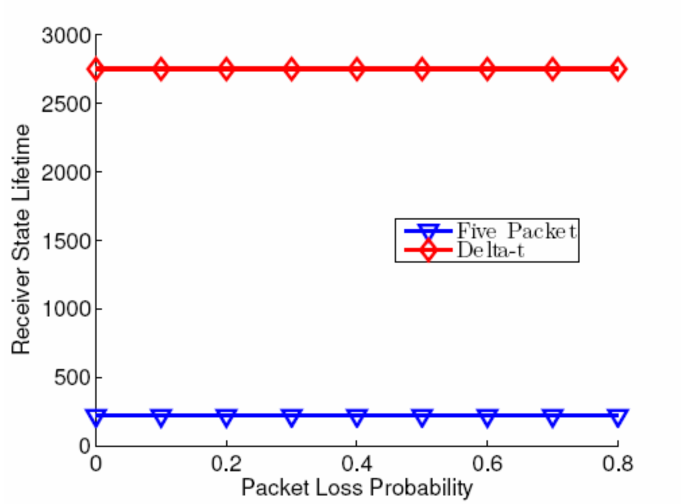
- Receiver State Lifetime

$$\eta = \frac{1}{\upsilon}\pi_{=}$$

Analytical Model Results



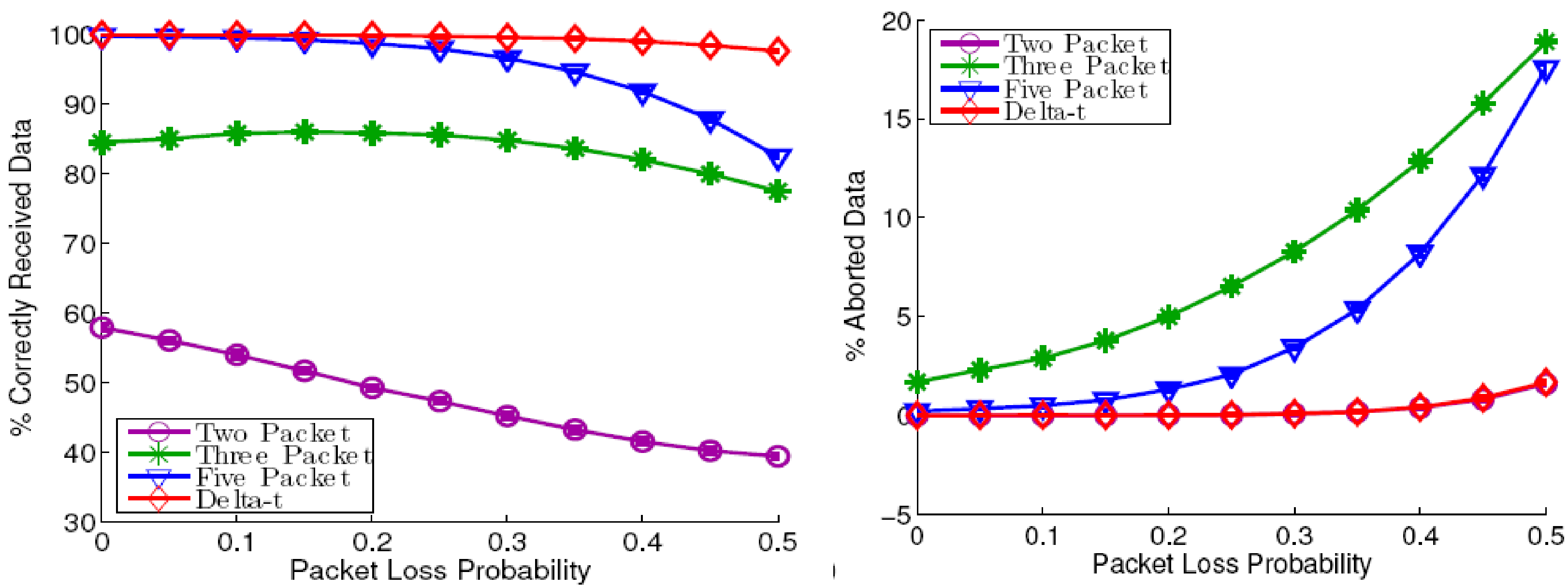




- Tradeoff between memory overhead/goodput and message rate

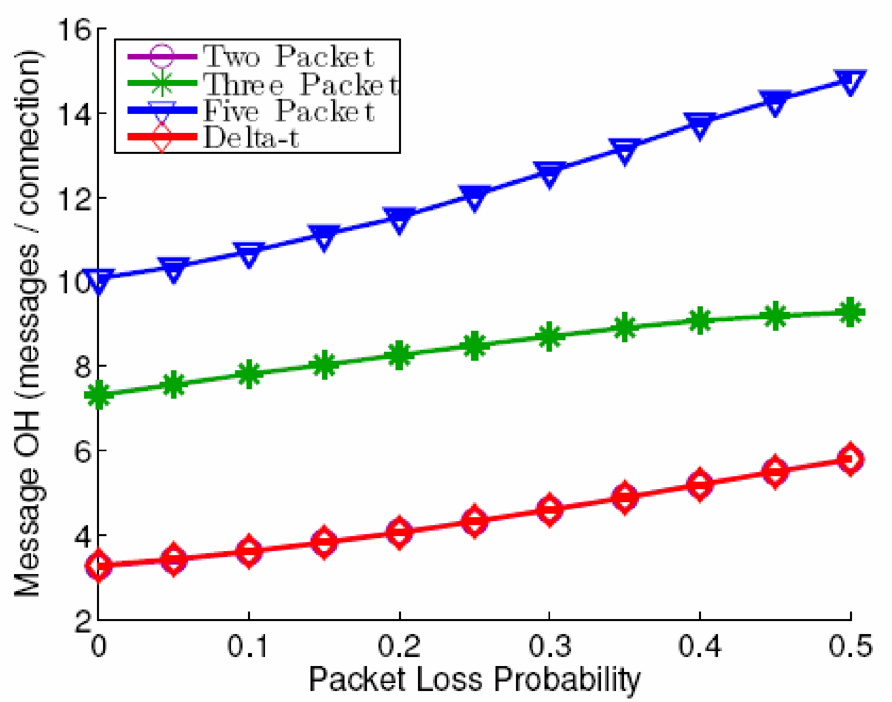
Simulation Results: Correctness

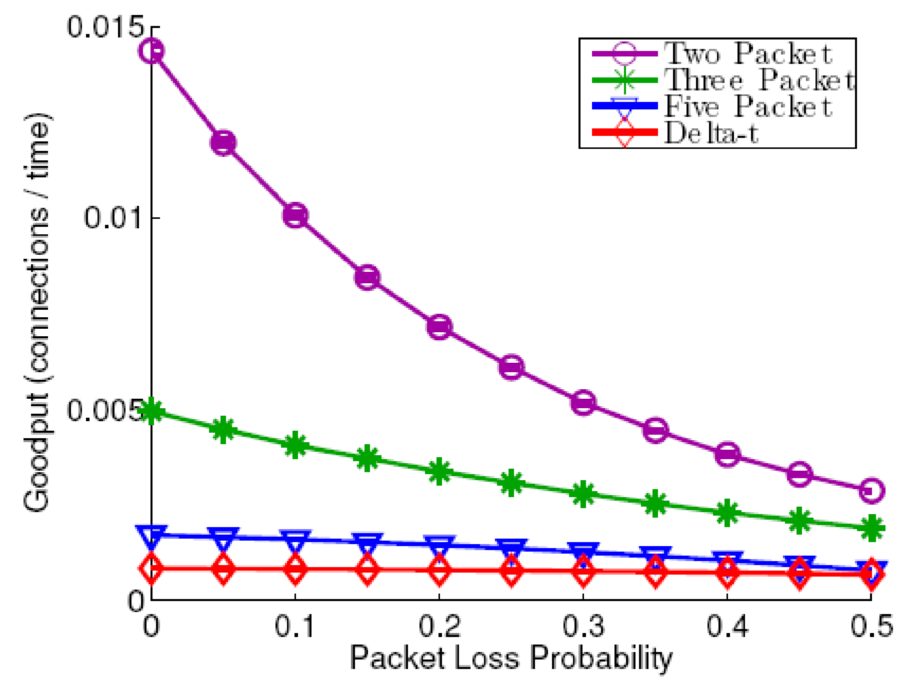
- Two-state channel-delay model, random initial sequence numbers



- SS (Delta-t) is more robust to bad net conditions

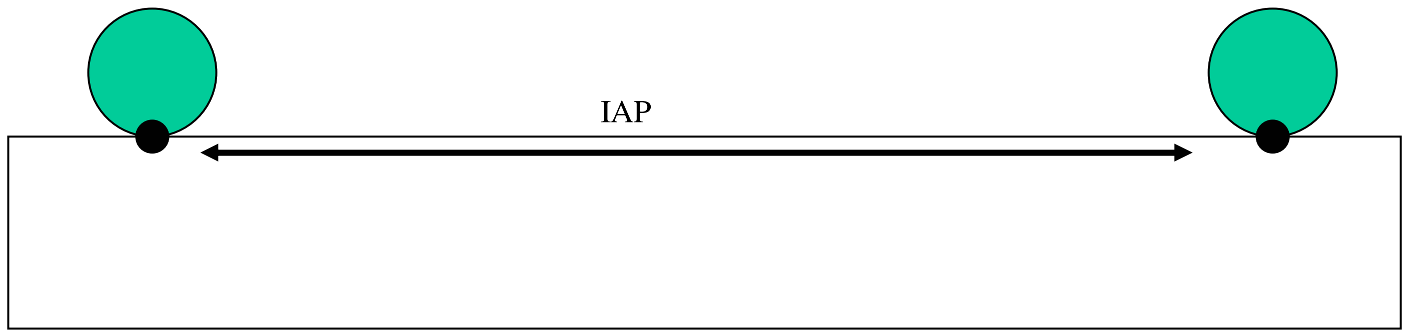
Simulation Results: Performance





- Goodput won't be limited given a reasonable conn ID space
- Memory requirement is not a concern
  - only 1.2MB needed at Delta-t receiver (server) in a typical setting

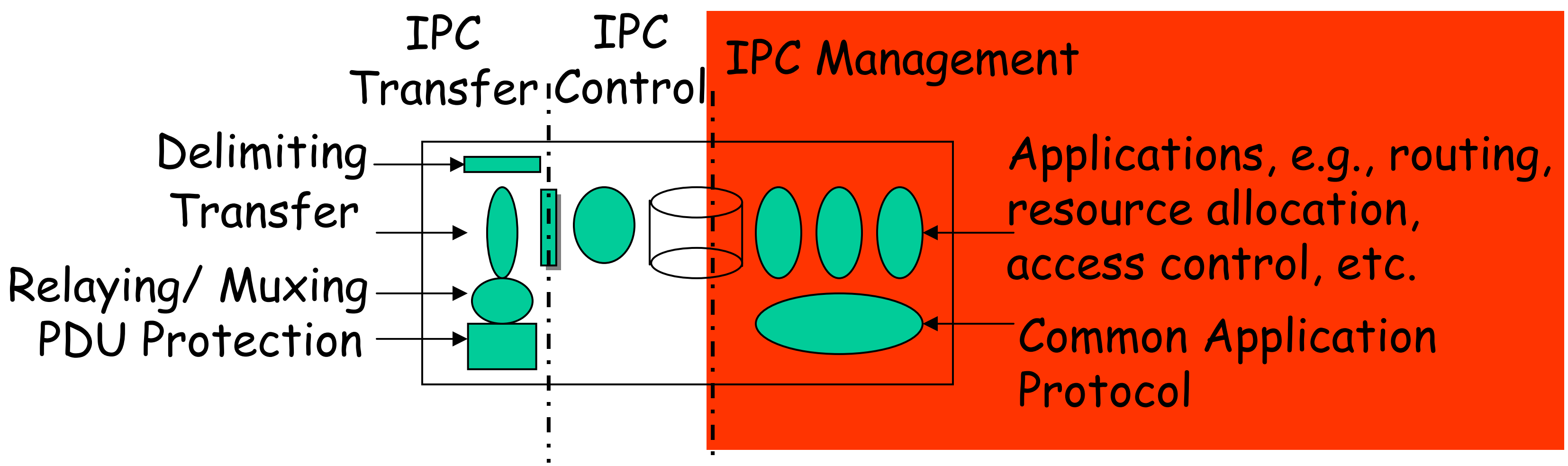
Only one Transfer Protocol



- Allocating conn ID (ports) is done by management, IPC Access Protocol (IAP)
- Once allocated Data Transfer can start, ala Delta-t
  - Flows without data transfer control are UDP-like. Different policies support different requirements
- If there is a long lull, state is discarded, but ports remain

All protocols are soft-state

- For management applications, need only one "stateless" (soft-state) application protocol to access objects
  - It does Read, Write, Create, Delete, Start, Stop
- The objects are outside the protocol
  - Other "protocols" may access the same objects



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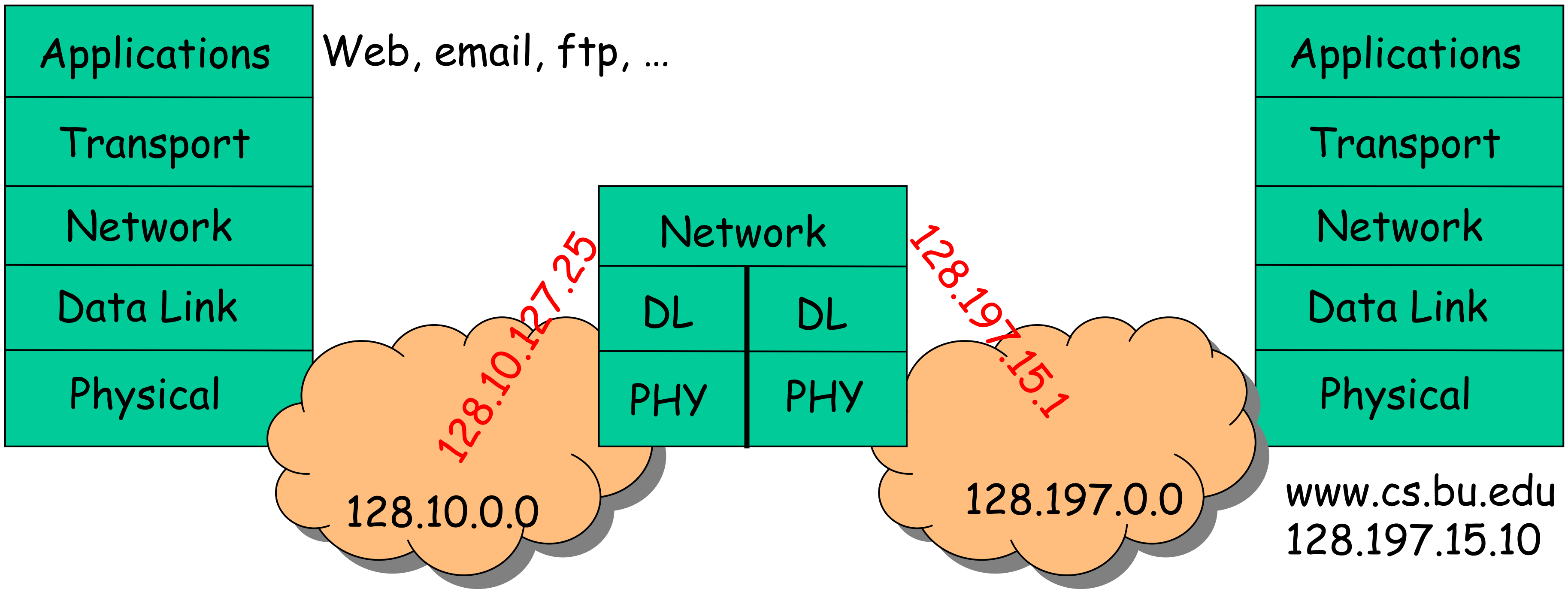
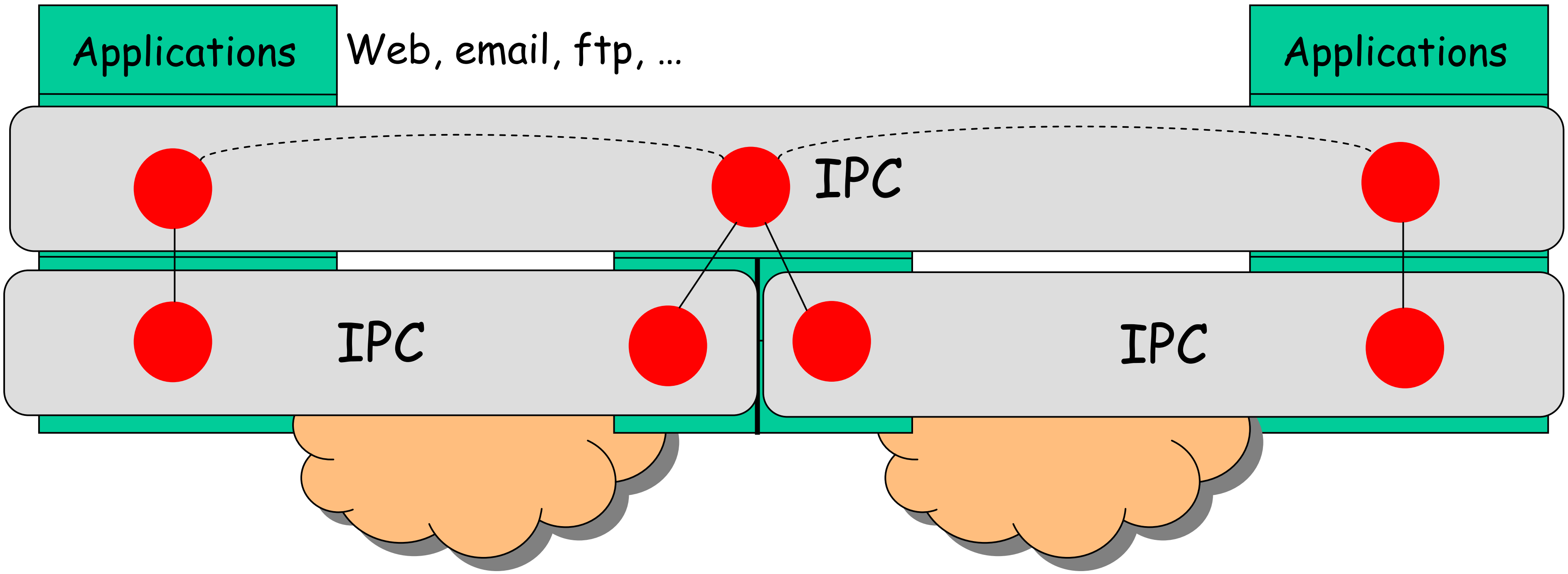
Compare to Current Stack (2)



- We exposed addresses to applications
- We named and addressed the wrong things

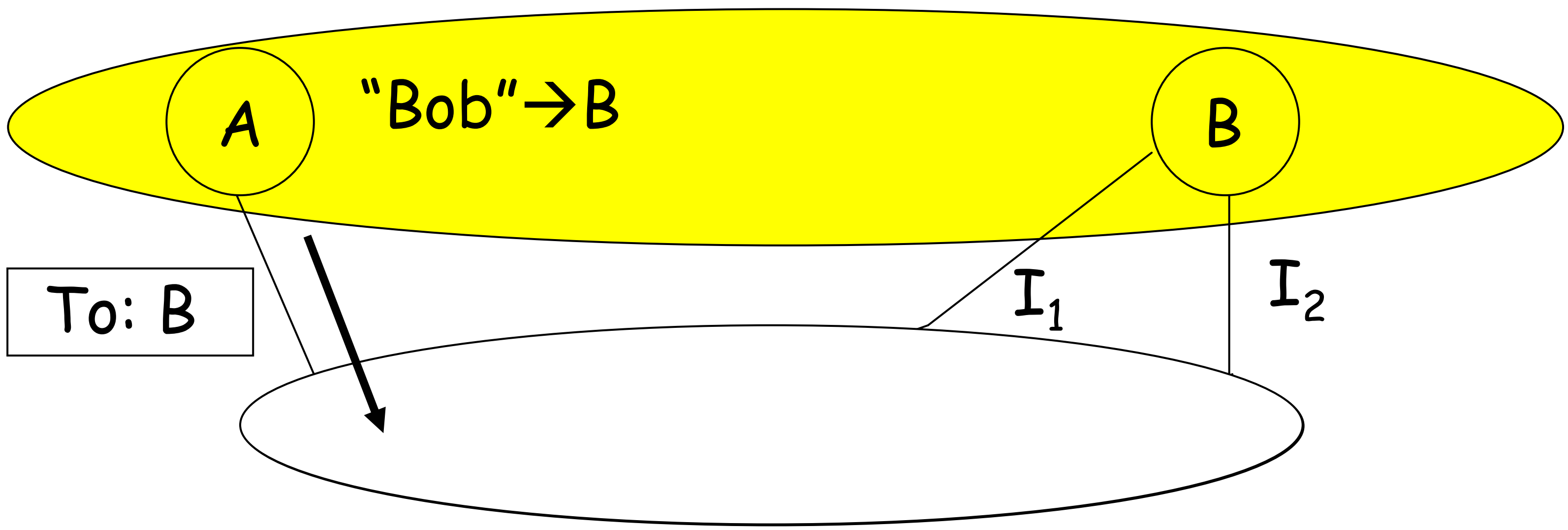
Compare to Current Stack (3)



- E2E (end-to-end principle) is not relevant
  - Each IPC layer provides service / QoS over its scope
- IPv6 is/was a waste of time!
  - We don't need too many addresses within a DIF

Good Addressing

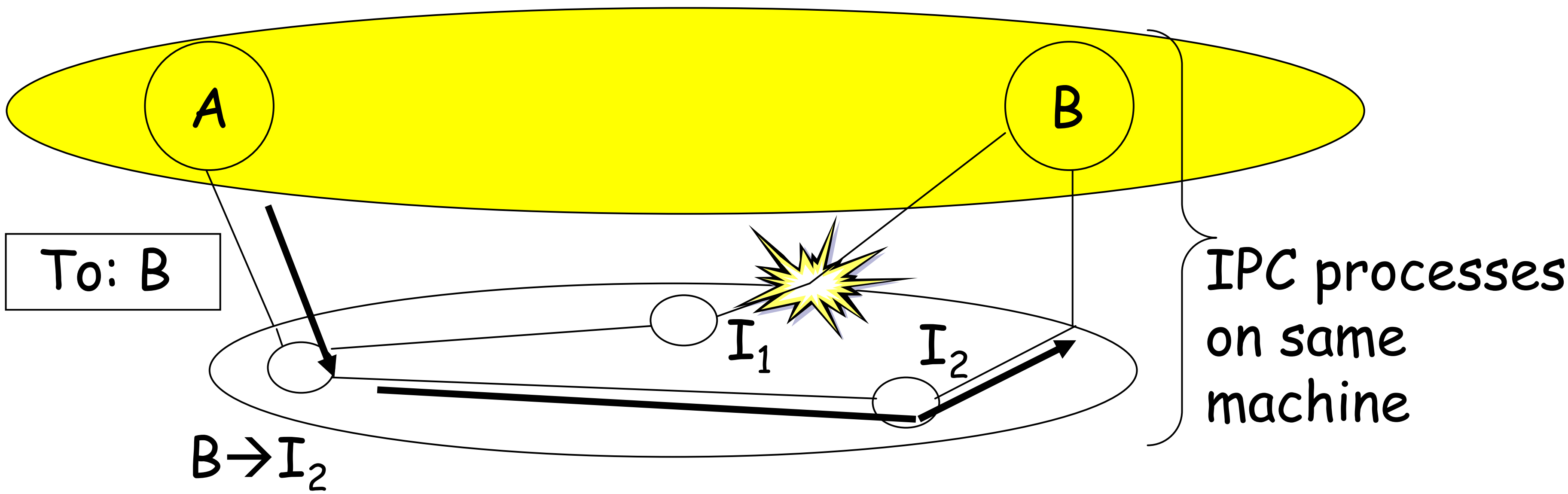
want to send message to "Bob"



- Destination application is identified by "name"
- App name mapped to node name (address)
- Node addresses are private within IPC layer
- Need a global namespace, but not address space
- Destination application process is assigned a port number dynamically

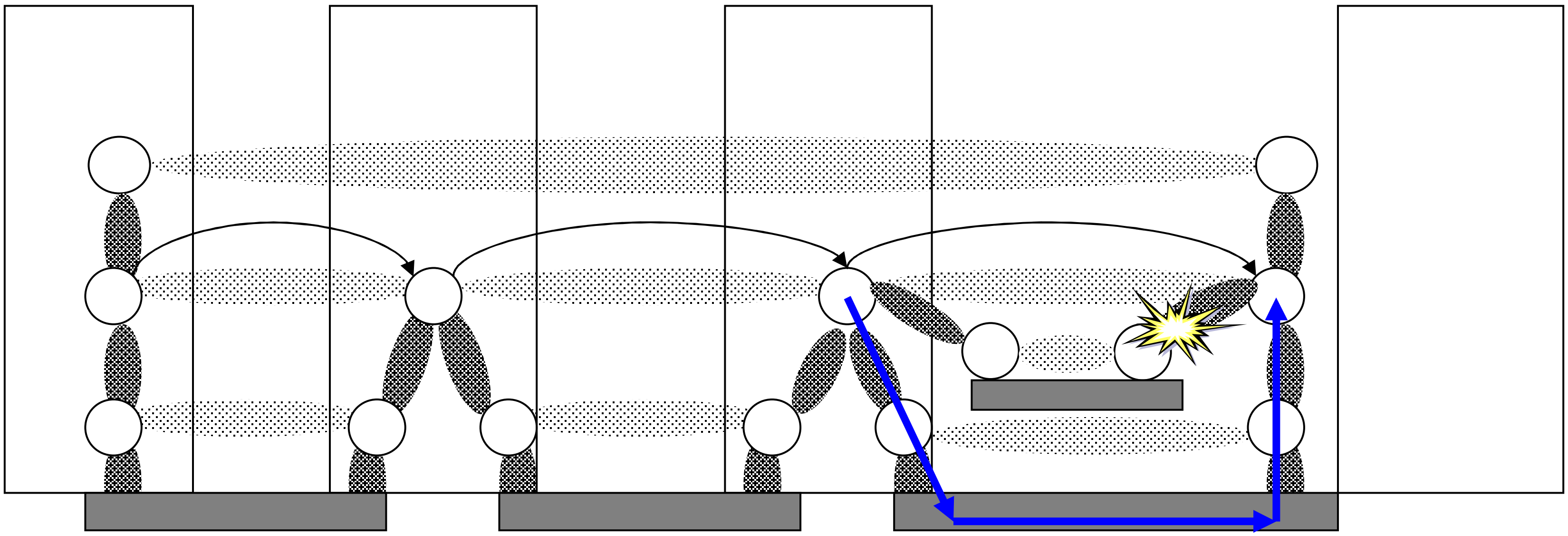
Good Addressing

want to send message to "Bob"



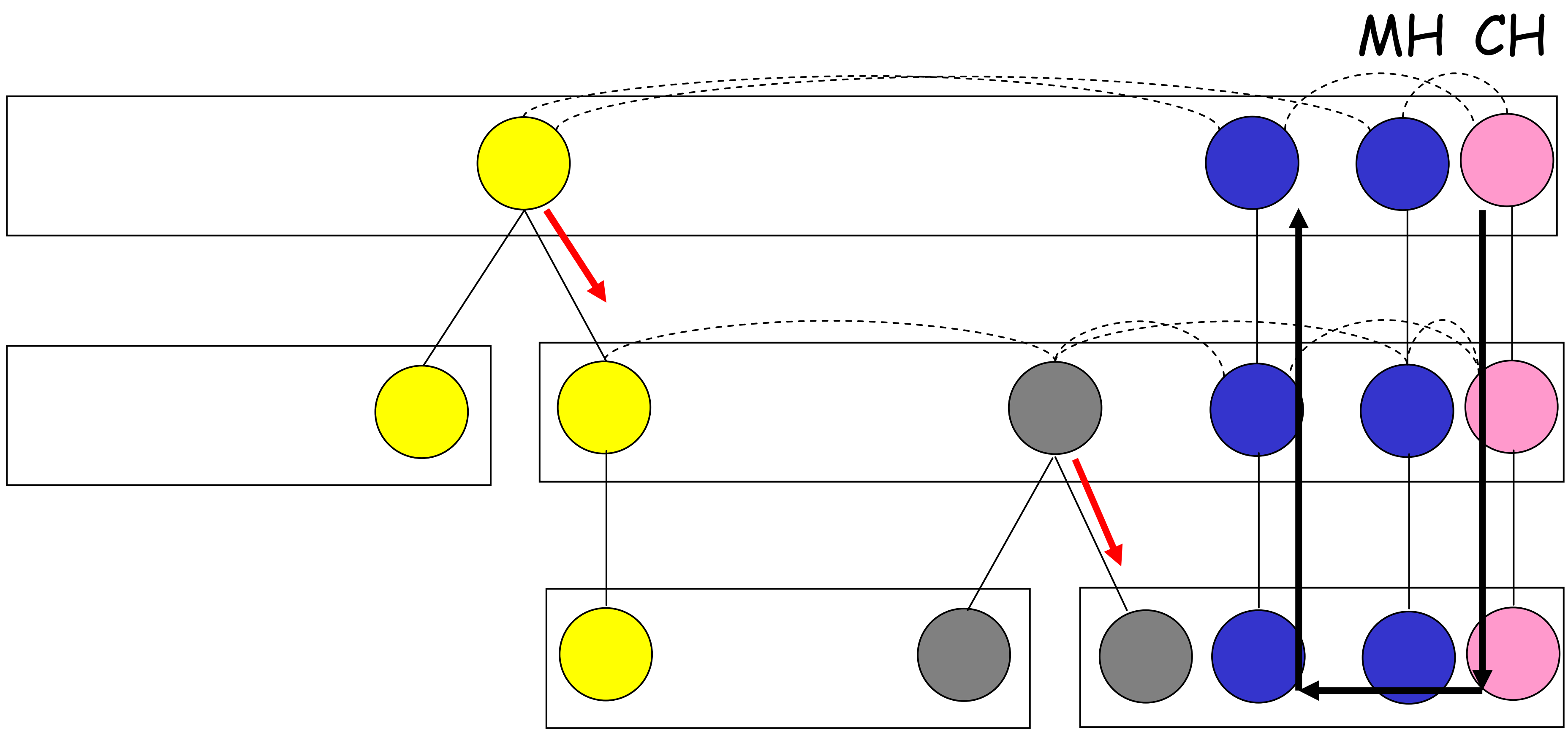
- Late binding of node name to a PoA address
- PoA address is "name" at the lower IPC level
- Node subscribes to different IPC layers

Good Routing



- Back to naming-addressing basics [Saltzer '82]
  - Service name (location-independent) → node name (location-dependent) → PoA address (path-dependent) → path
- We clearly distinguish the last 2 mappings
- Route: sequence of node names (addresses)
- Map next-hop's node name to PoA at lower IPC level

Mobility is Inherent



- Mobile joins new IPC layers and leaves old ones
- Local movement results in local routing updates

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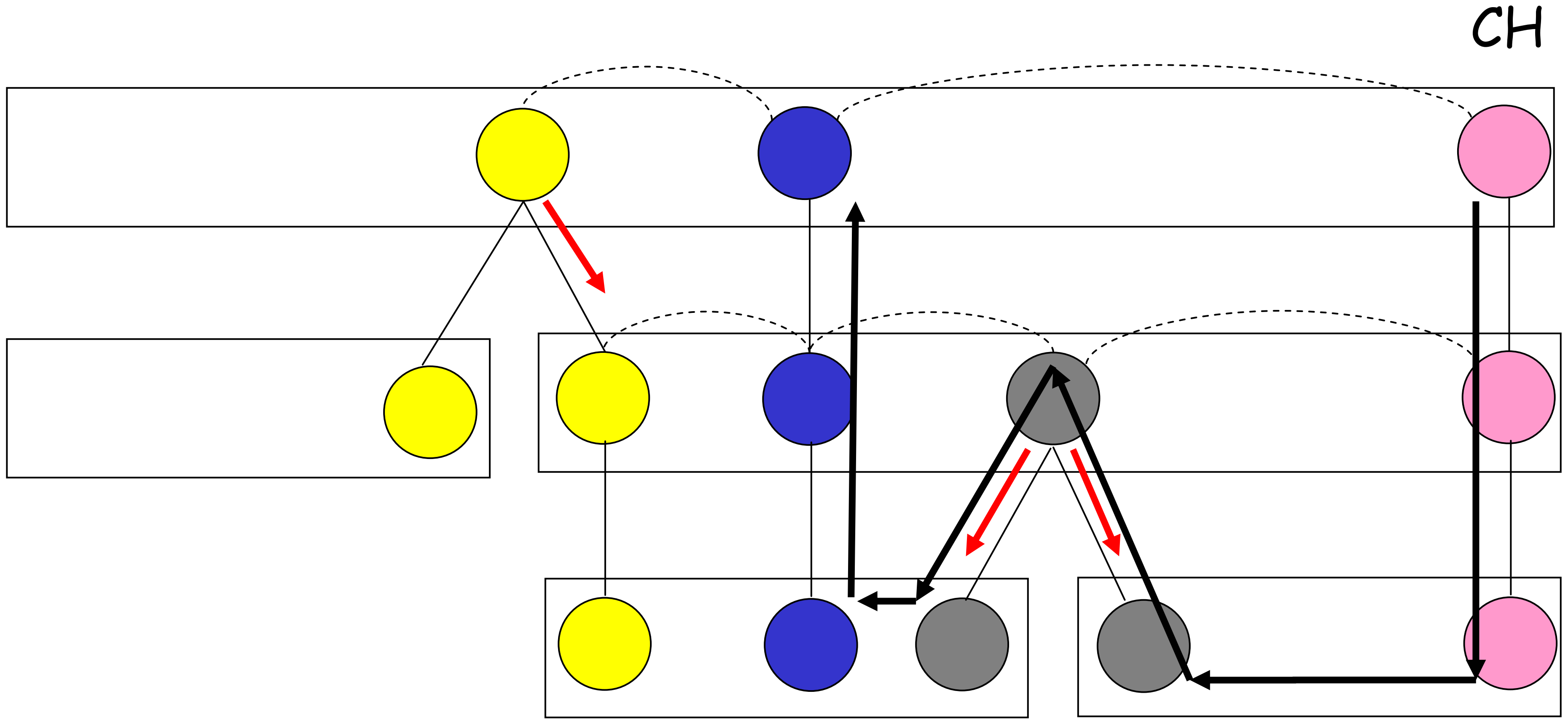

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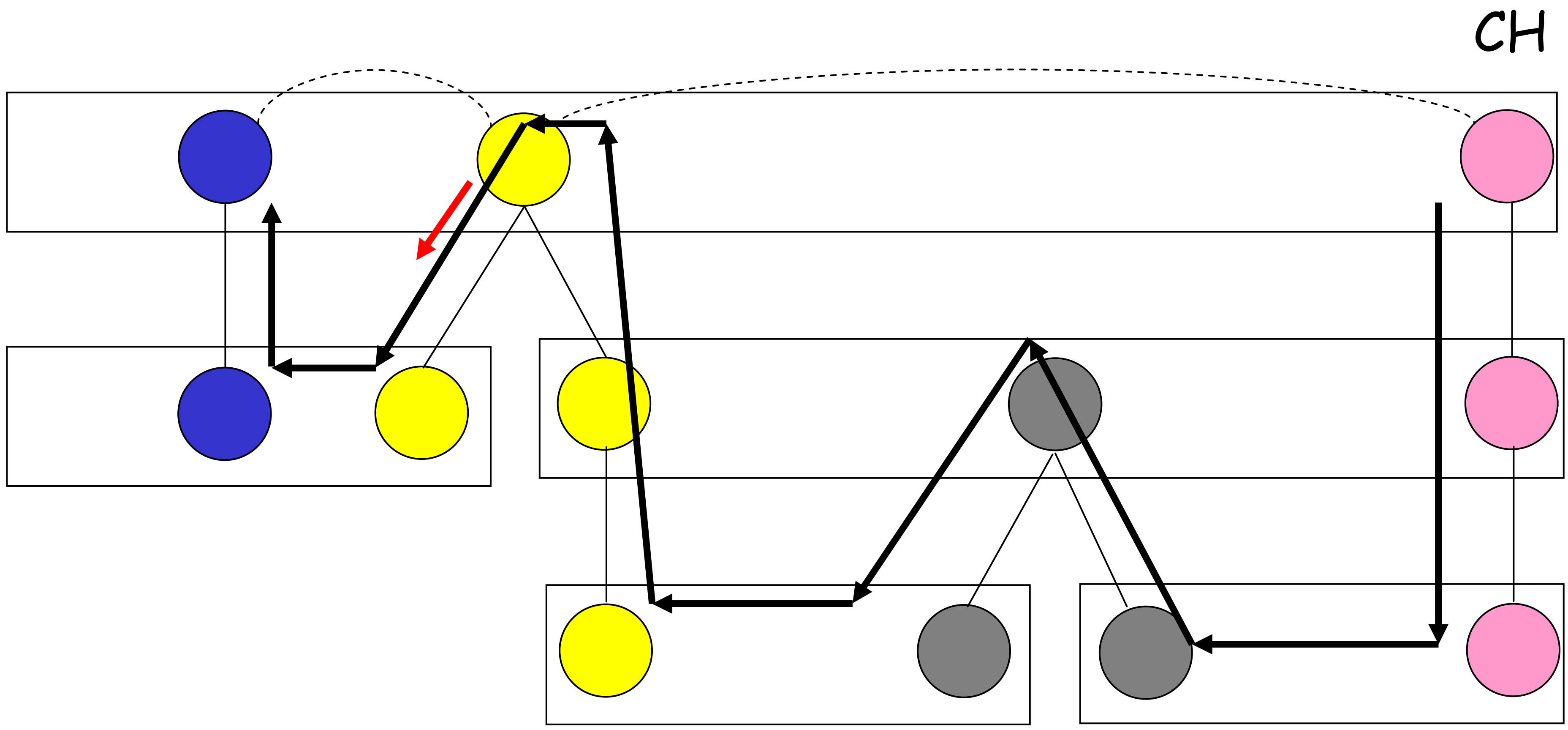

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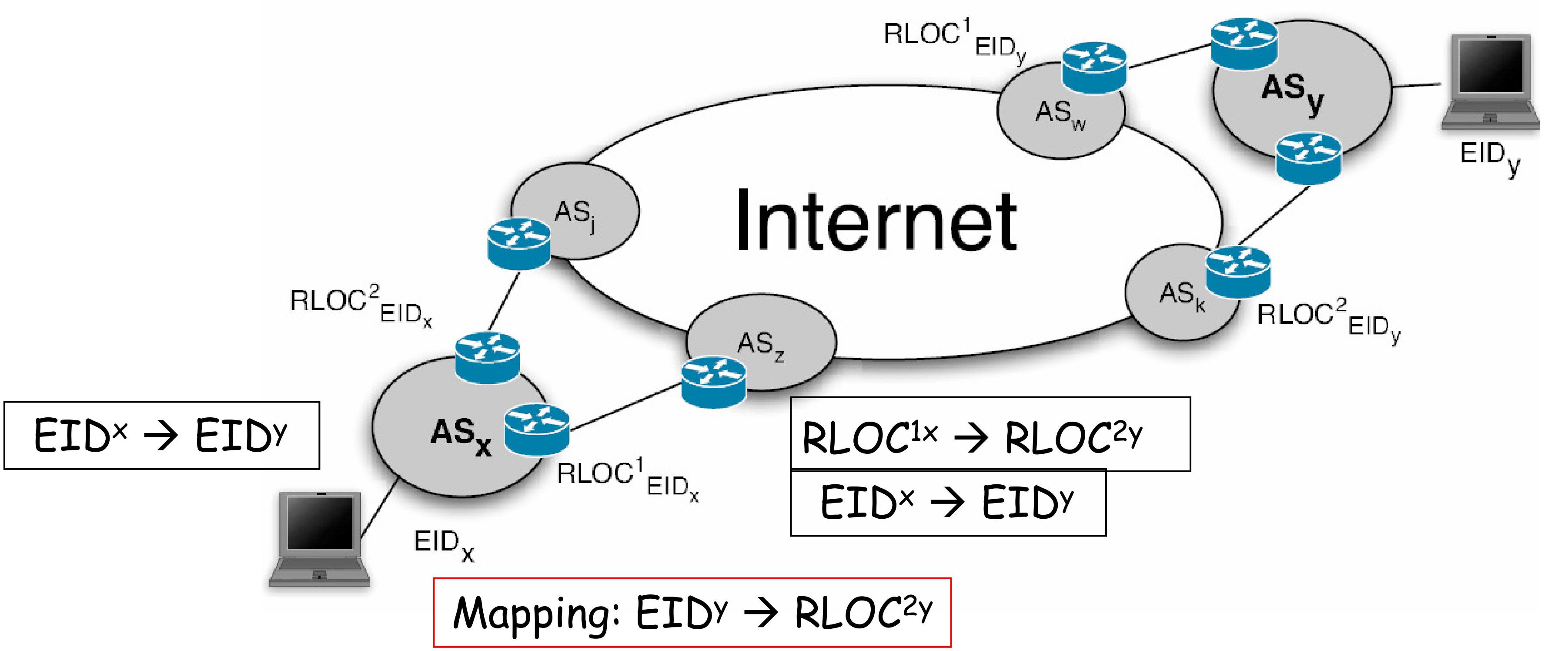
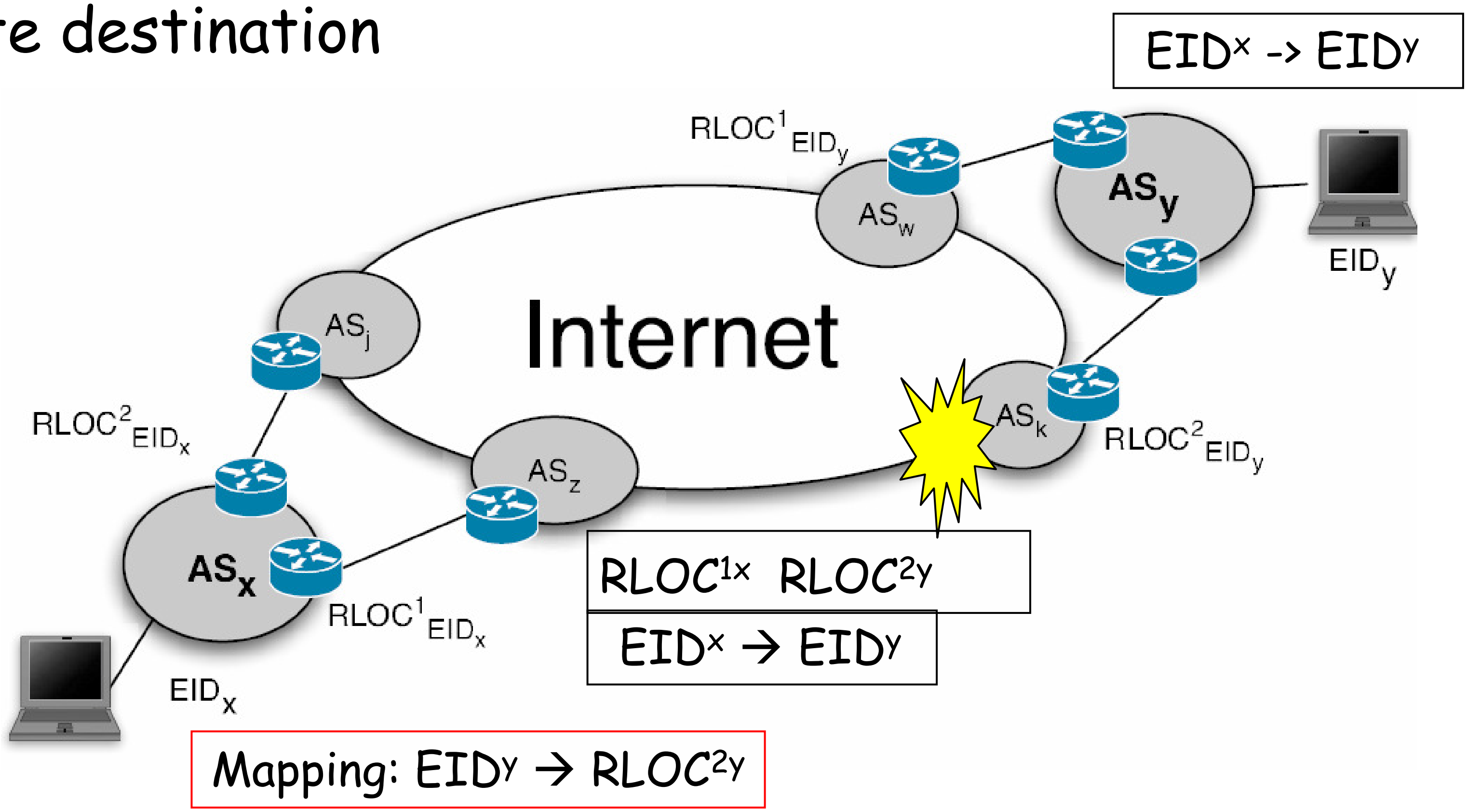
Compare to loc/id split (1)

- Basis of any solution to the multihoming issue
- Claim: the IP address semantics are overloaded as both location and identifier
- LISP (Location ID Separation Protocol) '06



Compare to loc/id split (2)

- Ingress Border Router maps ID to loc, which is the location of destination BR
- Problem: loc is path-dependent, does not name the ultimate destination

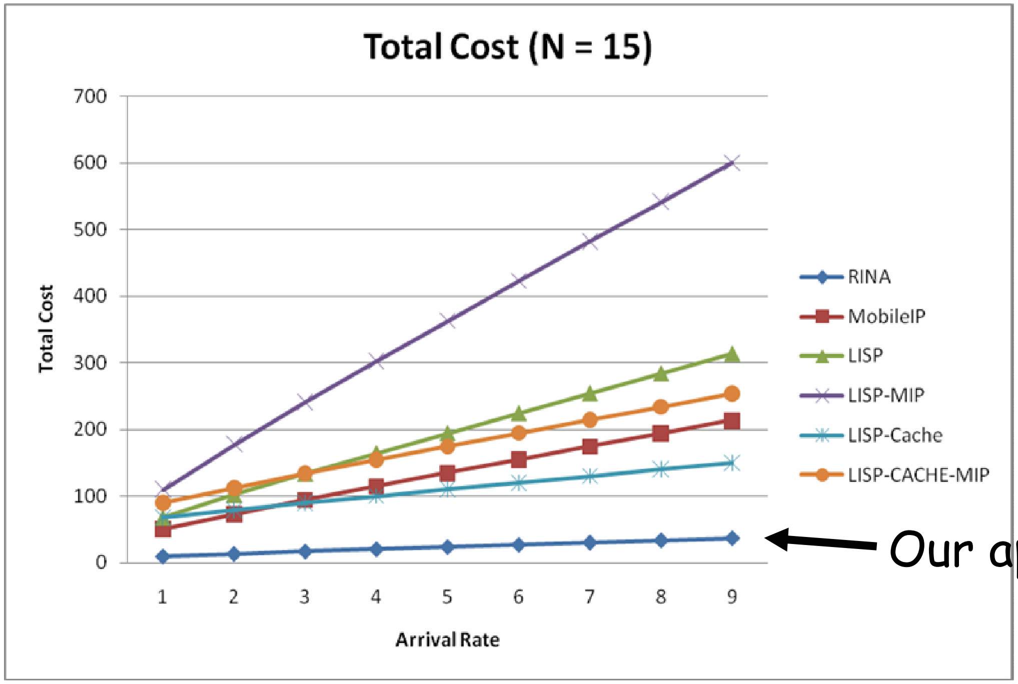


LISP vs. Our approach

- Total Cost per loc change = Cost of Loc Update + ρ [P_{cons}*DeliveryCost + (1-P_{cons})*InconsistencyCost]

ρ: expected packets per loc change

P_{cons}: probability of no loc change since last pkt delivery



Our approach

NxN Grid Topology

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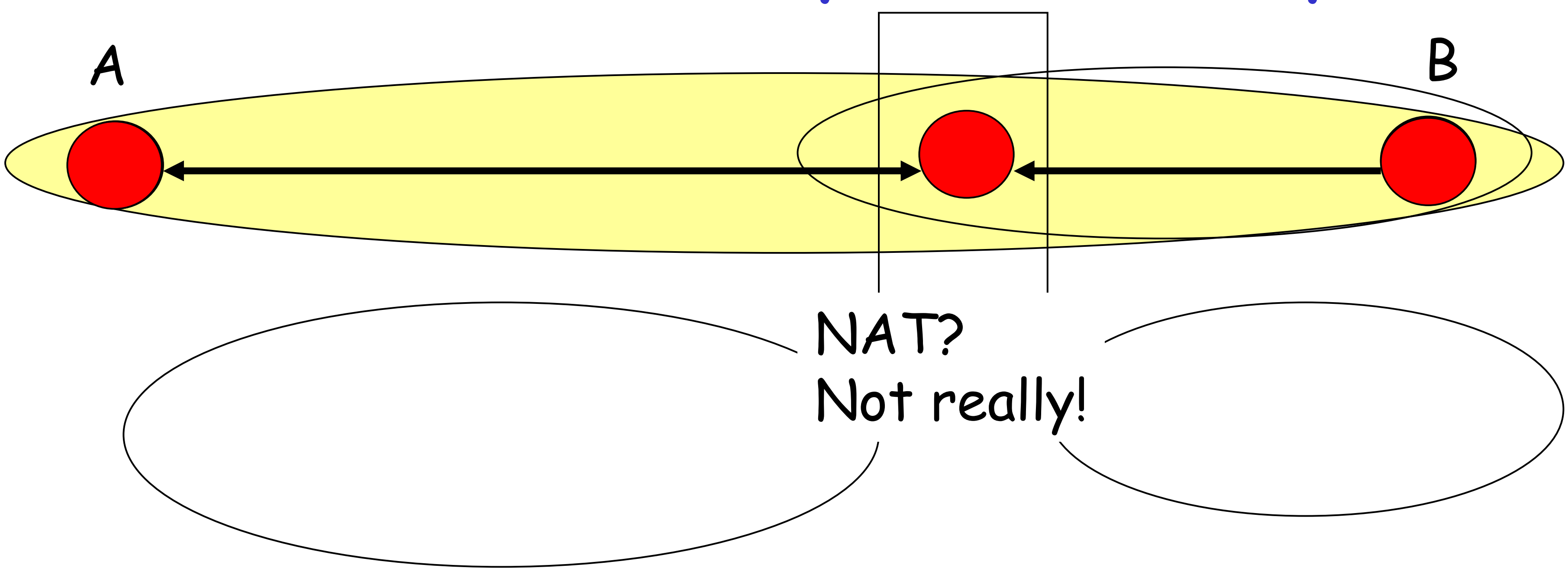
Better Scalability & Security



- Nothing more than applications establishing communication
  - Authenticating that A is a valid member of the DIF
  - Initializing it with current DIF information
  - Assigning it an internal address for use in coordinating IPC
  - This is enrollment

Adoptability

- ISPs get into the IPC business and compete with host providers
- A user joins any IPC network she chooses
- All IPC networks are private
- We could still have a public network with weak security properties, i.e., the current Internet
- Many IPC providers can join forces and compete with other groups

Related Work

- Back to networking basics
  - Networking is IPC and only IPC [Metcalfe '72]
  - We apply this principle all the way!
- Back to naming-addressing basics
  - Extend [Saltzer '82] to next-hop routing on node addresses
- Back to connection management basics
  - Use soft-state approach [Watson '81] within a complete arch.
- Recursive [Touch et al. '06] but we recurse IPC over different scopes
  - Beyond existing stack, "middleware", and "tunneling"
- Loc/id split [LISP '06] approaches
  - "loc" does not name the dest!

Current / Future Work

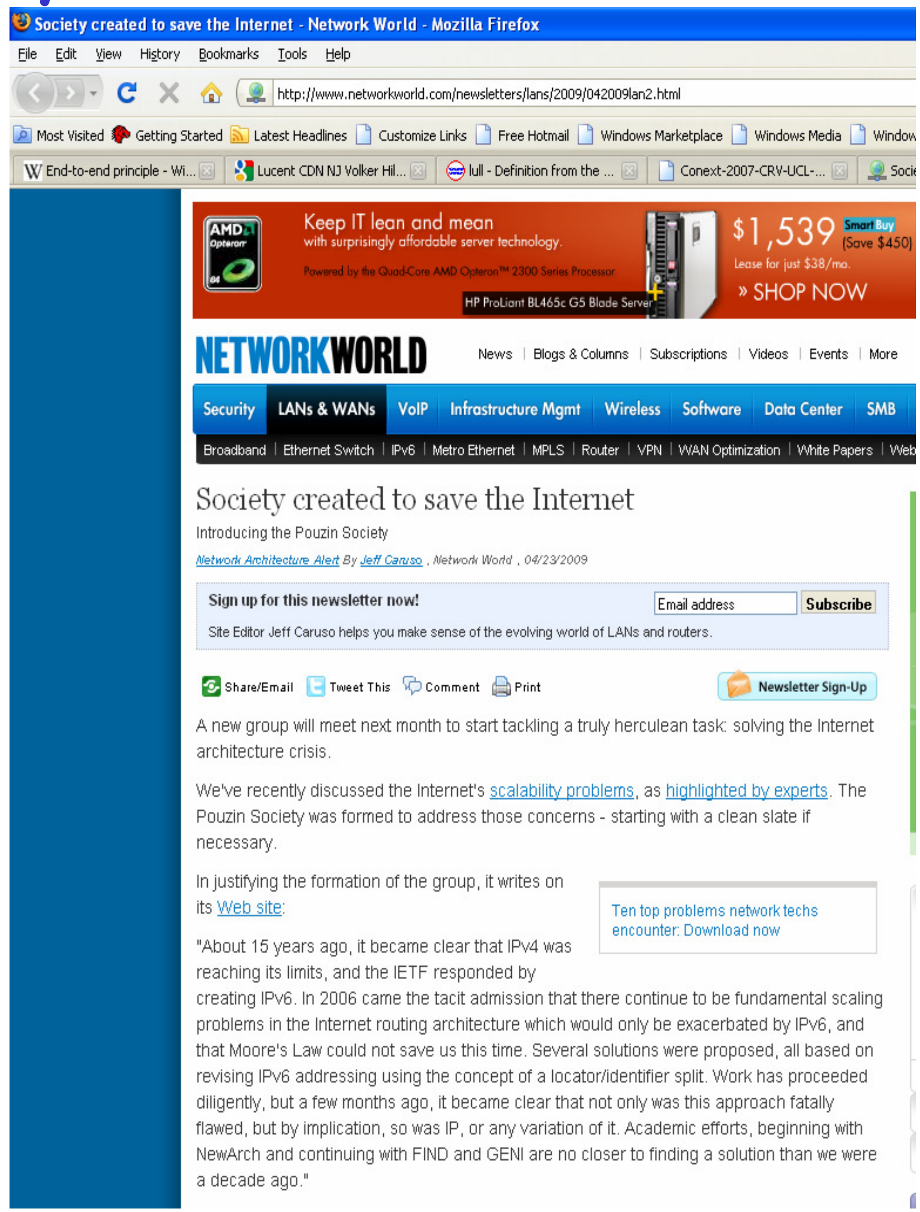
- Complete specification of IPC mechanism (data transfer & control) and management (routing, security, resource allocation, …)

- Fast implementation
  - Minimize data copying, context switching, …

- Declarative specification of policies

The Pouzin Society was formed …

- http://pouzinsociety.org/
- Email me (matta@cs.bu.edu) for more info



Thank You

Questions?