Resolving the Transport "Tussle"

Recursive InterNetwork Architecture

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What this is (NOT) about

- NOT much about specific protocols, algorithms, interfaces, implementation
- 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

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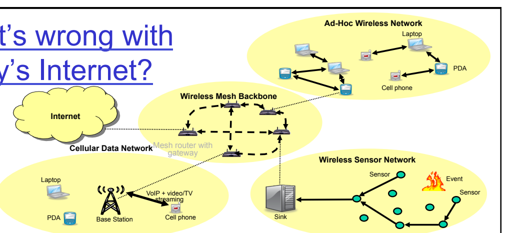
What's wrong with today's Internet?



- The new brave world
  - Larger scale, more diverse technologies
  - New services: content-driven, context-aware, mobile, socially-driven, secure, profitable, …
- Custom point-solutions: No or little "science"
- Lots of problems: Denial-of-service attacks, unpredictable performance, hard to manage, …

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Questions?

- Is the Internet's architecture fundamentally broken that we need to "clean slate"?
  - Yes
- Can we find a new architecture that is complete, yet minimal? If so, what is it?
  - RINA?
- Can we transition to it without requiring everyone to adopt it?
  - Yes

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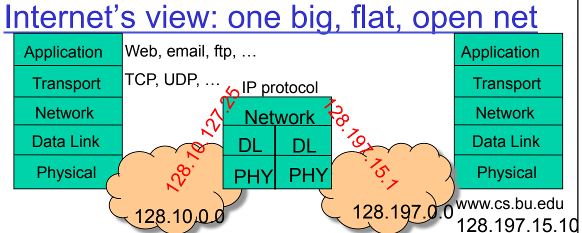
Internet's view: one big, flat, open net



- There's no building block
- The "hour-glass" model imposed a least common denominator
- Either didn't name what was needed or named the wrong things (i.e., interfaces)
- We exposed addresses to applications
- We hacked in "middleboxes"
- …

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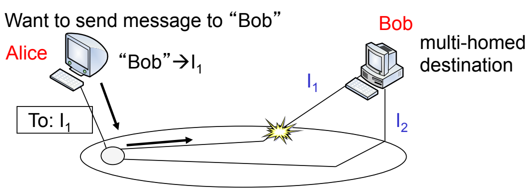
Ex1: Bad Addressing & Routing

Want to send message to "Bob"



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

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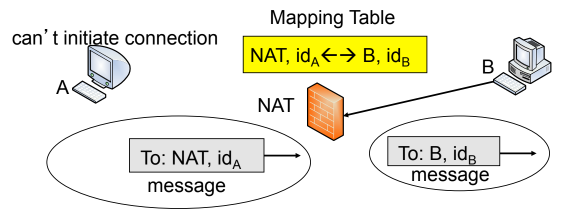
Ex2: Ad hoc Scalability & Security



- 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 a Distributed IPC Facility (DIF)
- DIF management is hidden from applications
  - ➔ better security
- IPC processes are application processes of lower IPC facilities
- Recurse as needed
  - ➔ better management & scalability
- Well-defined service interfaces
  - ➔ predictable service quality
  - Applications ask for a *location-independent service*
  - The underlying IPC layer maps it to a *location-dependent node name, i.e.* address

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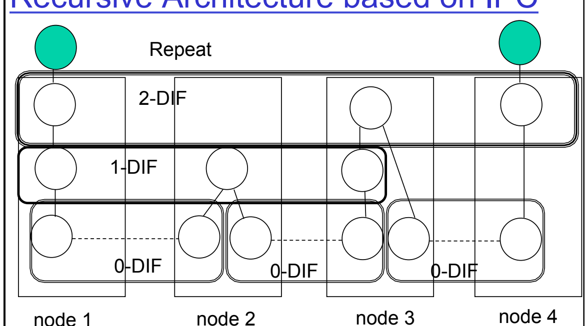
Recursive Architecture based on IPC



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

Policies are tailored to scope of DIF

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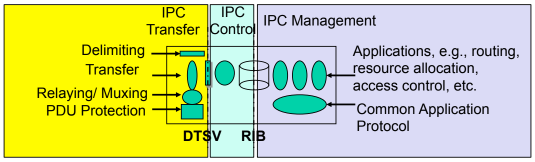
What Goes into a DIF?



- All what is needed to manage a “private” (overlay) network
  - A DIF integrates routing, transport and management
  - In TCP/IP, we artificially isolated functions of same IPC / scope

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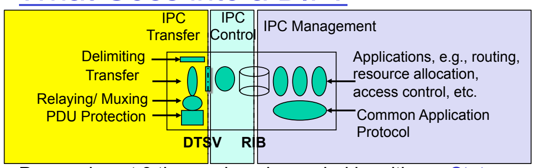
What Goes into a DIF?



- Processing at 3 timescales, decoupled by either a State Vector or a Resource Information Base
  - IPC Transfer actually moves the data (*tightly coupled* mechanisms)
  - IPC Control (optional) for error, flow control, etc. (*loosely* coupled)
    - Good we split TCP, but we split it in the wrong direction!
  - IPC Management for routing, resource allocation, locating applications, access control, monitoring lower layer, etc.
    - We need only one “stateless” Common Application Protocol to access objects: CREATE, DELETE, UPDATE, …

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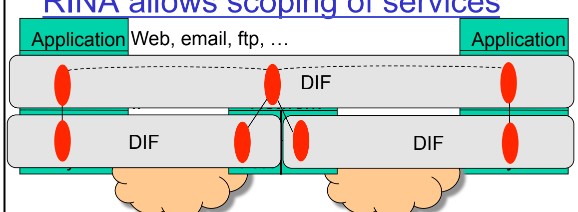
RINA allows scoping of services



- The DIF is the building block and can be composed
- Good we split TCP, but we split TCP in the wrong direction!
- E2E (end-to-end principle) is not relevant
  - Each DIF layer provides (transport) service / QoS over its scope
- IPv6 is/was a waste of time! A single ubiquitous address space is unnecessary
  - Have many levels without too many addresses within a DIF layer

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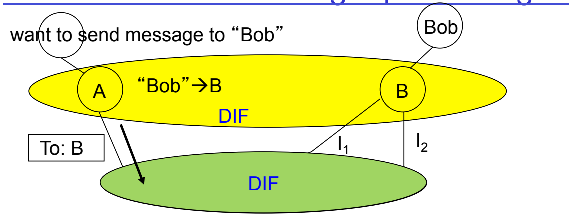
RINA: Good Addressing – private mgmt



- Destination application is identified by "name"
- Each IPC Layer (DIF) is privately managed
  - It assigns private node addresses to IPC processes
  - It internally maps app/service name to node address
  - Need a global namespace, but not address space
  - Destination application process is assigned a port number dynamically

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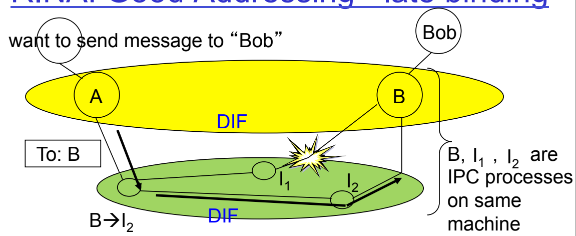
RINA: Good Addressing - late binding



- Addressing is relative: node address is name for lower IPC Layer, and point-of-attachment (PoA) for higher IPC Layer
- Late binding of node name to PoA address
- A machine subscribes to different DIF layers

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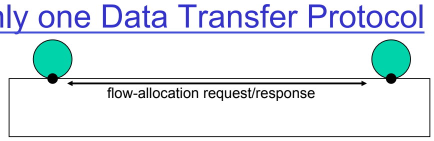
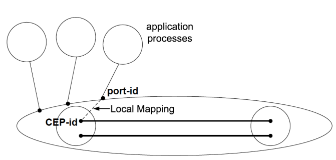
Only one Data Transfer Protocol



- In RINA, service is accessed by its application name
- Port allocation and access control decoupled from data transfer
- At each end, port and conn ID are allocated dynamically and bound to each other by management, in a hard-state fashion



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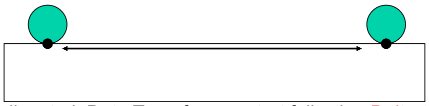
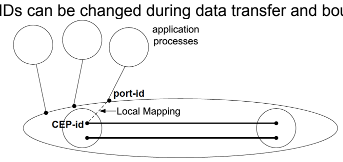
Only one Data Transfer Protocol (2)



- Once allocated, Data Transfer can start following Delta-t [Watson' 81], a soft-state protocol
  - Flows without data transfer control are UDP-like. Flows without reliability requirement do not ACK. Different policies support different requirements
  - If there is a long idle period, conn state is discarded, but ports remain
  - Conn IDs can be changed during data transfer and bound to same ports



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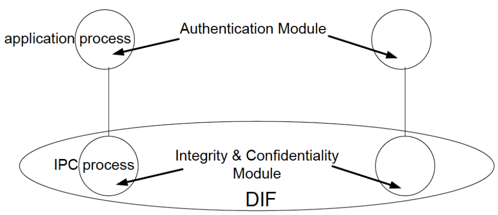
Where security goes …

- Authentication and encryption are applied recursively – no "shim" sublayers



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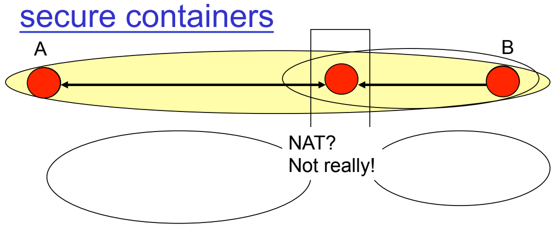
RINA: Better Scalability & Security – secure containers



- 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, i.e. explicit negotiation to join DIF (access control)
  - RINA decouples *authentication* *from* *connection management and integrity/confidentiality*

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Port Scanning Attacks

- Goal: first step for an attack, explore “open” ports
- In RINA, requesting applications never see addresses nor conn IDs
  - No well-known ports
  - Ports, dynamically allocated, are not part of conn IDs
  - Service requested by application name
- Traditional port scanning attacks not possible
- Scanning application names is much more difficult
- Attacker has to join the DIF too
  - For the sake of comparison, we assume the attacker overcame this hurdle!

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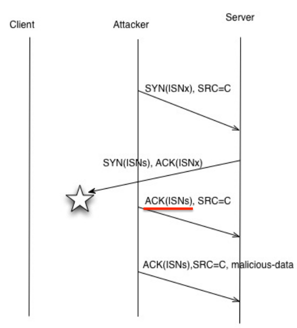
Connection Opening Attacks: TCP/IP

- Attacker has to guess server’s Initial Sequence Number (ISN)
- Given 32-bit sequence number, 2^{32} possibilities



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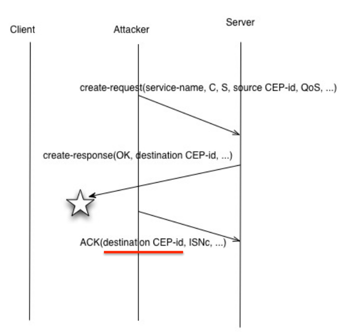
Connection Opening Attacks: RINA

- Attacker has to guess destination CEP-id
- Given 16-bit CEP-ids, 2^{16} possibilities
- Akin to port-scanning attacks, which raise more suspicion
- Client can use any ISN



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Data Transfer Attacks

TCP/IP

- Goal is to inject a legitimate packet, *e.g.* TCP "reset"
- Attacker has to guess source port and SN within transmission window
- Given 16-bit port numbers and 16-bit max window, $2^{16} * 2^{(32-16)=16}$ = 2^{32} guesses

RINA

- **Right before data transfer starts**
- Attacker has to guess conn IDs and QoS ID
- Given 8-bit QoS ID, $2^{(16+16+8)}$ = 2^{40} guesses
- **During data transfer**
- Attacker has to also guess SN, so $2^{(40+16)}$ = 2^{56} guesses
- Note: RINA can change conn IDs on the fly

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Attacking the reassembly of TCP segment

- Attack by inserting malicious data into IP fragment carrying part of TCP payload
- Not possible in RINA
- Transport and relaying are integrated in each DIF layer
- Fragmentation/reassembly is done once as data enters/leaves the DIF layer

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Good Design leads to Better Security

- In RINA, requesting apps never see addresses nor conn IDs
  - → traditional port scanning attacks not possible
- Underlying IPC processes must be authenticated to join DIF
  - → only "insider" attacks possible
  - → a hurdle that is not present in TCP/IP networks

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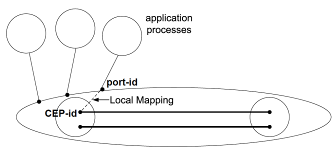
Good Design leads to Better Security (2)

- Conn IDs are allocated dynamically, so they are hard to guess
- State of data transfer is soft, so there aren't explicit control messages to fabricate
  - Note: Delta-t was developed in the 80's with NO consideration for security!



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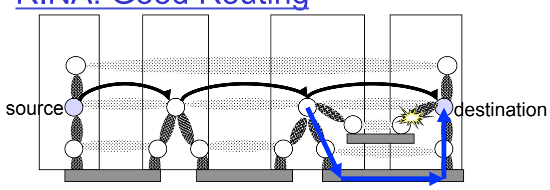
RINA: Good Routing



- 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)
- **Late binding** of next-hop' s node name to PoA at lower DIF level

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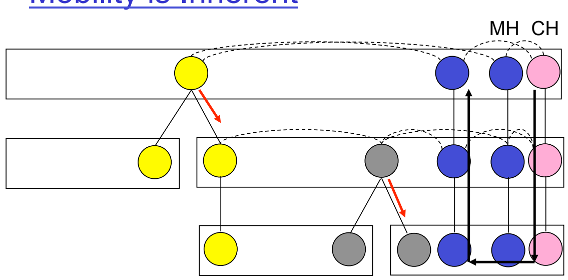
Mobility is Inherent



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

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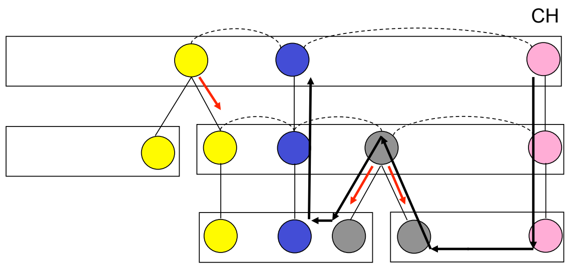
Mobility is Inherent



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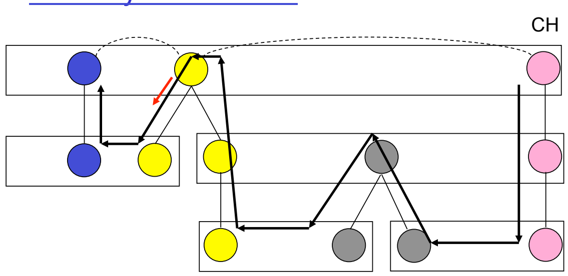
Mobility is Inherent



- Mobile joins new DIF layers and leaves old ones
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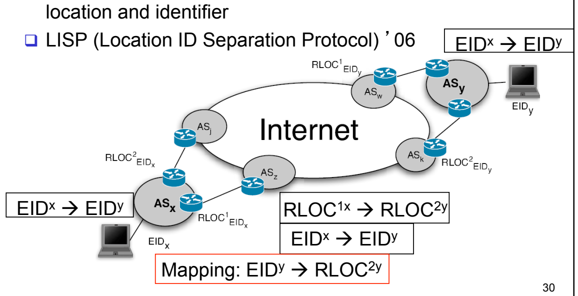
Compare to loc/id split (1)

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



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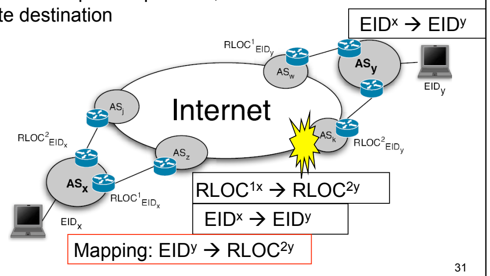
Compare to loc/id split (2)

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



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LISP vs. RINA vs. …

- Total Cost per loc / interface change = Cost of Loc / Routing 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

- RINA's routing modeled over a binary tree of IPC Layers: update at top level involves route propagation over the whole network diameter D; update at leaf involves route propagation over $D/2^h$, h is tree height

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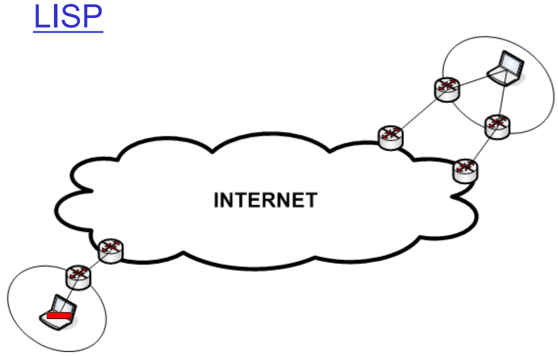
LISP



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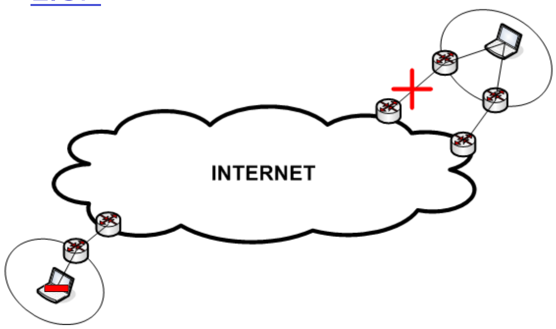
LISP



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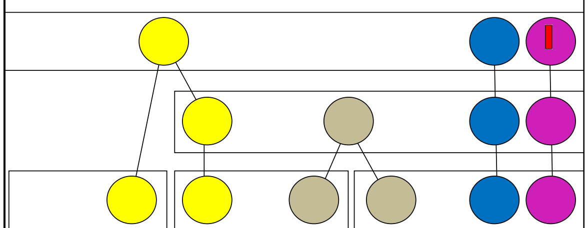
RINA



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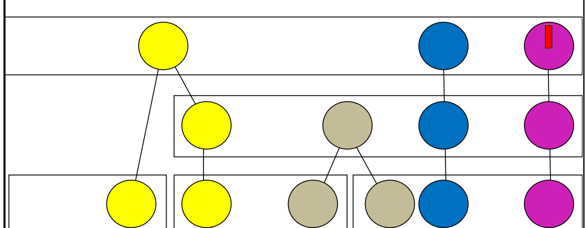
RINA



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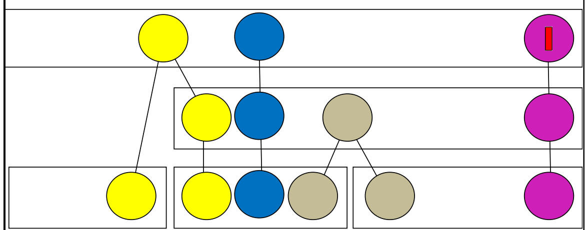
RINA



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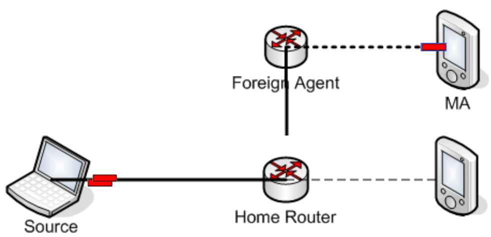
MobileIP



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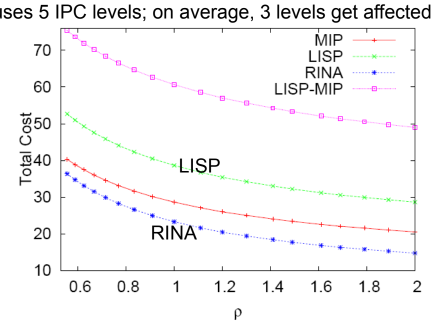
LISP vs. RINA vs. …

8x8 Grid Topology

RINA uses 5 IPC levels; on average, 3 levels get affected per move



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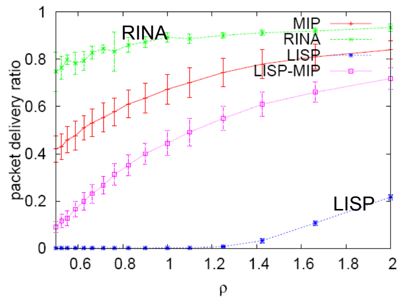
Simulation: Packet Delivery Ratio

- BRITE generated 2-level topology
- Average path length 14 hops
- Random walk mobility model
- Download BRITE from www.cs.bu.edu/brite



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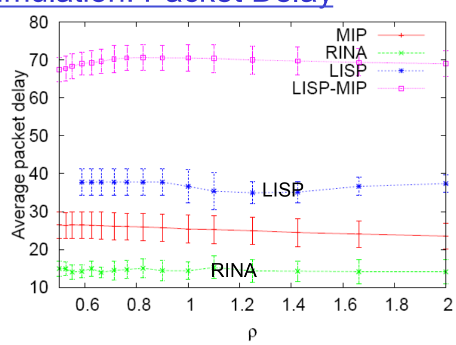
Simulation: Packet Delay



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Bottom Line: RINA is less costly

- RINA inherently limits the scope of location update & inconsistency
- RINA uses “direct” routing to destination node

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Adoptability

- ISPs get into the IPC business and compete with host providers
  - Provide transport services everywhere
- 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

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RINA A Better Network Structure

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