CS551
Scalable Wide-area Upload
[Bistro00]

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http://merlot.usc.edu/cs551-f12

Bistro

a Platform for Building Scalable Wide-Area *Upload* Applications

Scalable Data Transfer Applications

End-system / Application-level

		# of Receivers	
		One	Many
# of Senders	One		
	Many		

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Scalable Data Transfer Applications

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Scalable Data Transfer Applications

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	Many		*chat rooms* *video conferencing* *multiplayer games* *...*

Scalable Data Transfer Applications

End-system / Application-level

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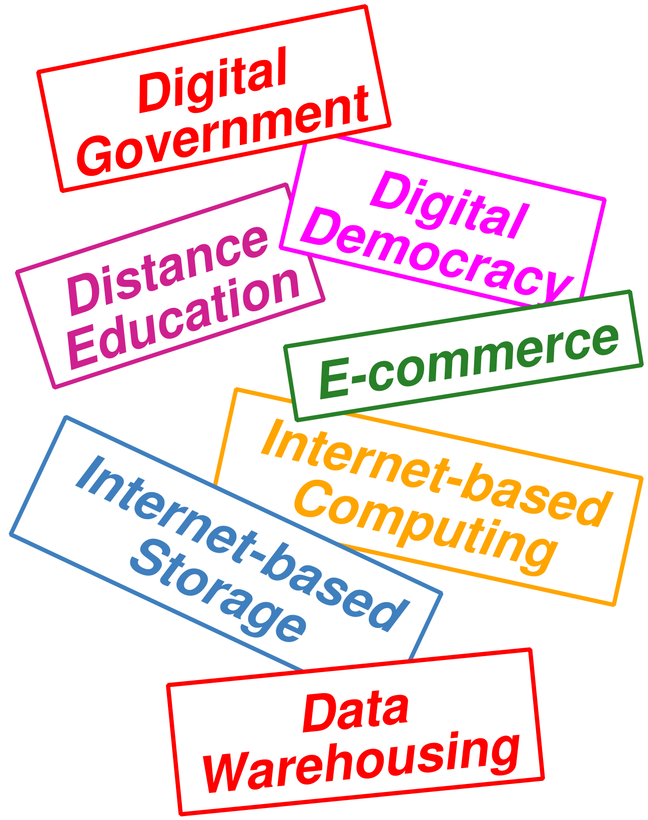
# of Senders	One	*ftp* *traditional apps* *...*	*web downloads* *software distribution* *video-on-demand* *server push* *...*
	Many	*Bistro!!*	*chat rooms* *video conferencing* *multiplayer games* *...*

Who Is Working on Uploads?

- To the best of our knowledge, there is no existing work on making *many-to-one* communication at the *application* layer *scalable* and *efficient*

What Are *Upload* Applications?

- ***Hard deadlines***
  - IRS income tax submission
  - paper submission
  - ⇒ *real-life events*
- ***No hard deadlines***
  - Internet-based storage
  - Data warehousing



Why is *Upload* Different?

- many-to-one data transfer
- read vs. ***write***
  - traditional solution such as replication of data (caching), replacement of data, etc. won't help
  - fault tolerance, ***security***
- contention for service rather than data
- data consumed later *(will exploit this)*

- **replication of services and resources for a single event is expensive, inflexible, & not scalable**

Traditional Approaches

(at the application layer)

- **Increase capacity**
- **Spread the load ... over time, space, or both**
- **Change the workload**

- **Examples**
  - **data replication** *ftp mirroring, web caching*
  - **data replacement** *multi-resolution images, video*
  - **service replication** *DNS lookup, NTP*
  - **server push** *news download, software distribution*

Traditional Approaches (Cont...)

Example: Akamai

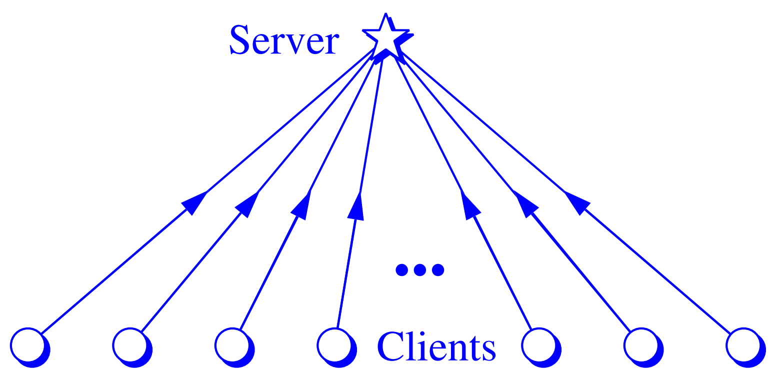
- Relieve web download hotspots through data replication (caching)
- Use their own network of servers, with strategic placement of servers around the world
  - *> 2700 servers*
  - *> 45 countries*
  - *> 150 networks*
- Clients include: Microsoft, Paramount, Wired, CBS Sports, Nike, BBC America, Apple, ...
  - *Why are there hotspots?*
    - real-life events
    - *availability of new data*

Our Goals

- A single infrastructure (termed *Bistro*) for all *data collection* needs
  - good performance (for both service providers and users)
  - scalable (shares resources among all service providers)
  - secure (one service provider does not have to trust another)

Current State of Affairs for Uploading

- Independent data transfers over the Internet, i.e., TCP/IP
  - TCP/IP shares bandwidth fairly
  - individual clients experience poor performance when number of clients is large (if transfer time is long enough to *see* other connections)
  - TCP/IP is here to stay

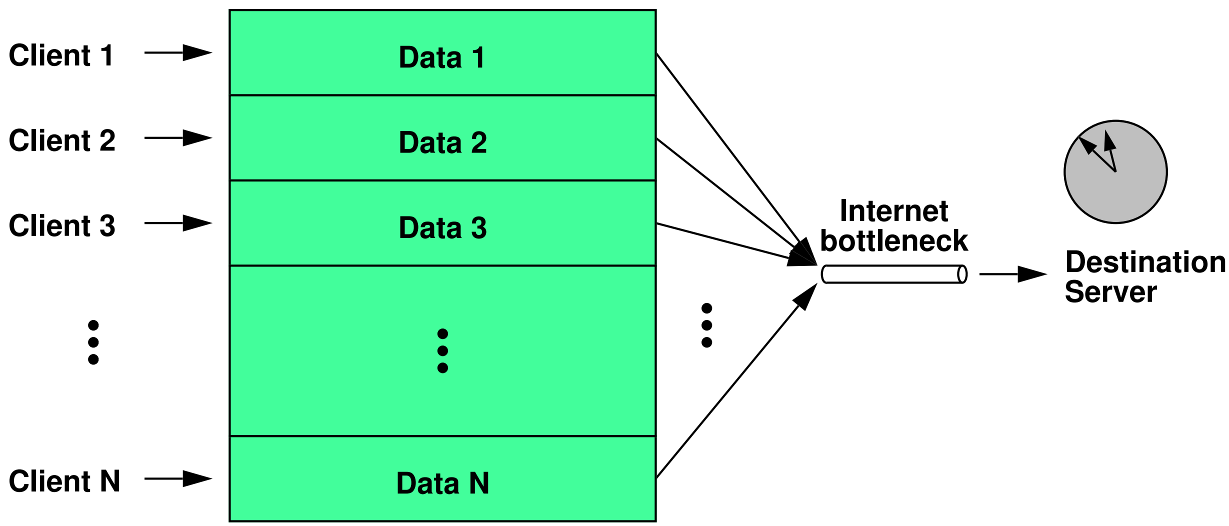


- ***Not scalable!***

Key Observations

(applications with deadlines)

- **Existence of hot spots in uploads is largely due to *approaching deadlines***
- **Exacerbated by *long transfer times***
- **Problem: too much data ... too little time ...**



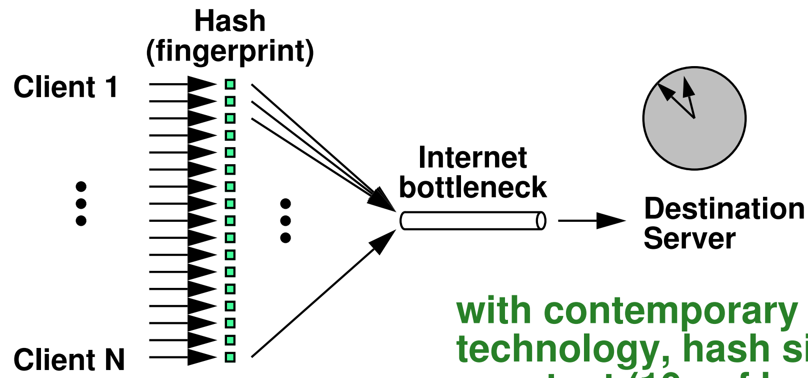
Key Observations (Cont...)

(applications with deadlines)

- What is actually needed is an *assurance* that specific data was submitted before a specific time
  - i.e., we need a *commitment* of *what* and *when* a submission took place
- Then the transfer of that data needs to be done in a timely manner, but does *not* have to occur by the deadline
  - unlink downloads, the data may not be consumed at the server right away
  - if a piece of data arrives after the deadline, we just need to guarantee that it's exactly the same piece of data that was committed before the deadline

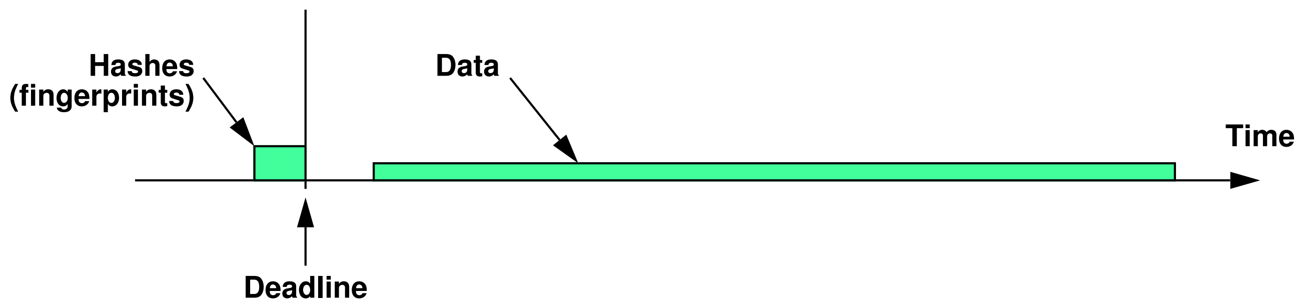
Solution with *Bistro*

- **Before deadline:**

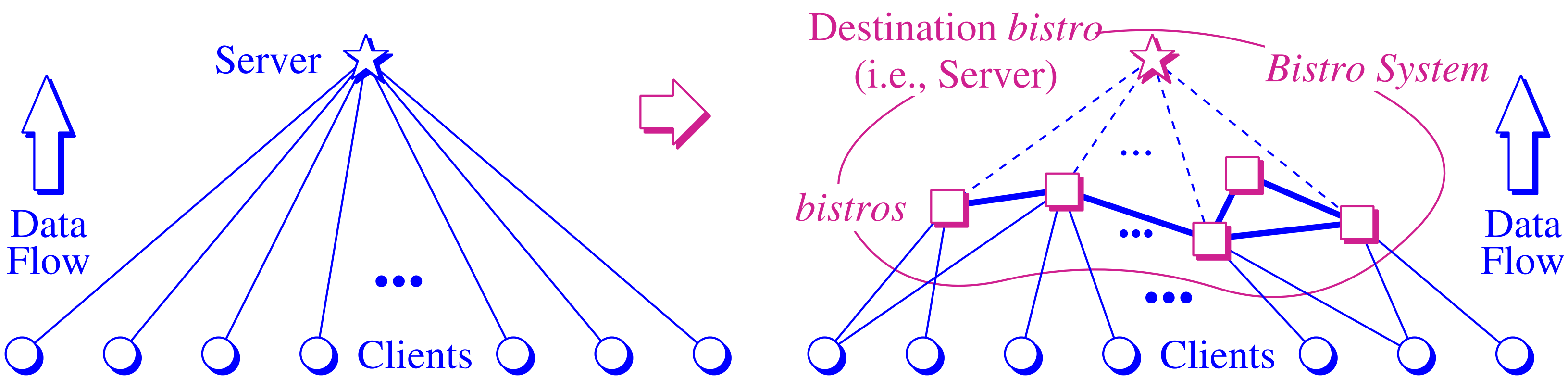


with contemporary cryptography technology, hash size is constant (10s of bytes), no matter how big a document is

- **Traffic at/near *Destination Server:***



A Solution to *Upload* with *Deadlines*

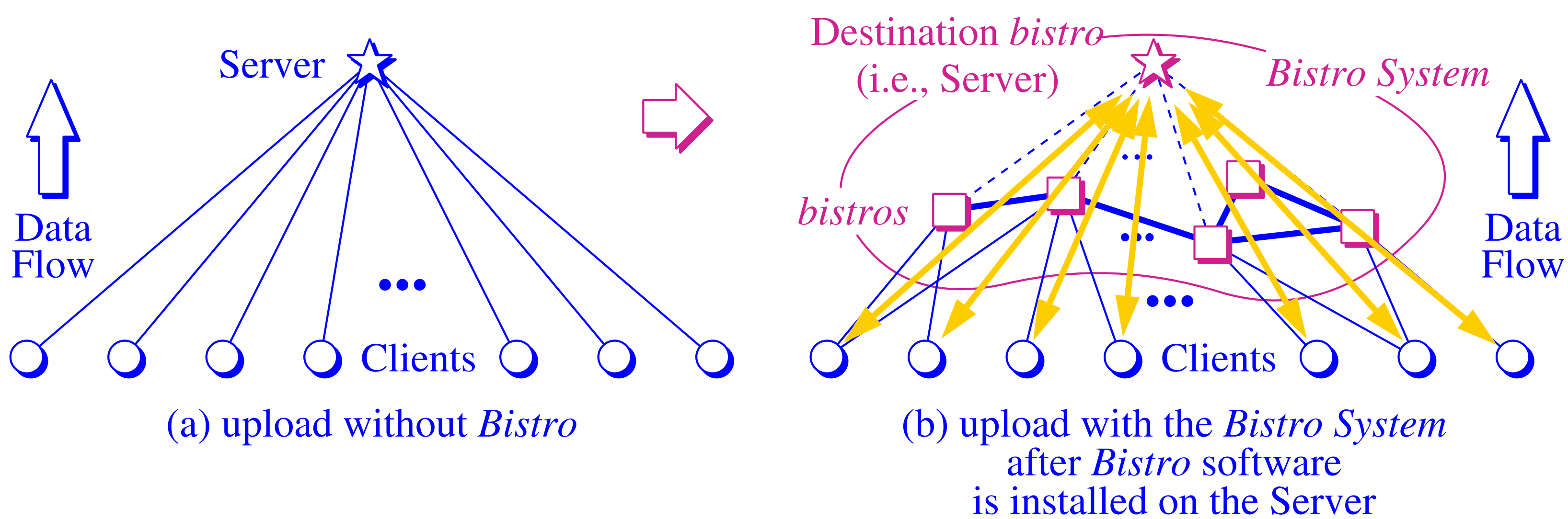


(a) upload without *Bistro*

(b) upload with the *Bistro System* after *Bistro* software is installed on the Server

- A ***bistro*** is like an ***e-Post Office***, built to handle ***certified e-submissions***
- A bistro can be installed on an IRS server or a tax partner's server
- Note:
  - Picutre above is for a *single event, e.g., 2005 personal income tax submission*
  - Multiple events may be going on concurrently or overlapping, each with a different destination server

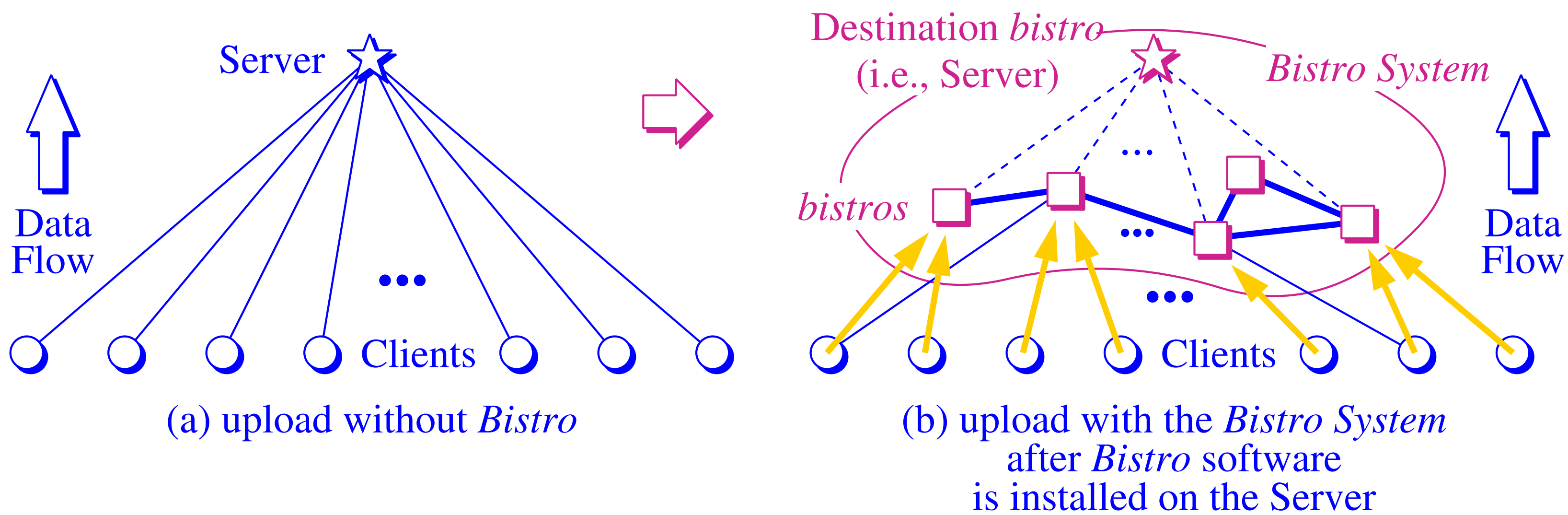
A Solution to *Upload* with *Deadlines*



Step 1: Real-time fingerprinting & timestamp

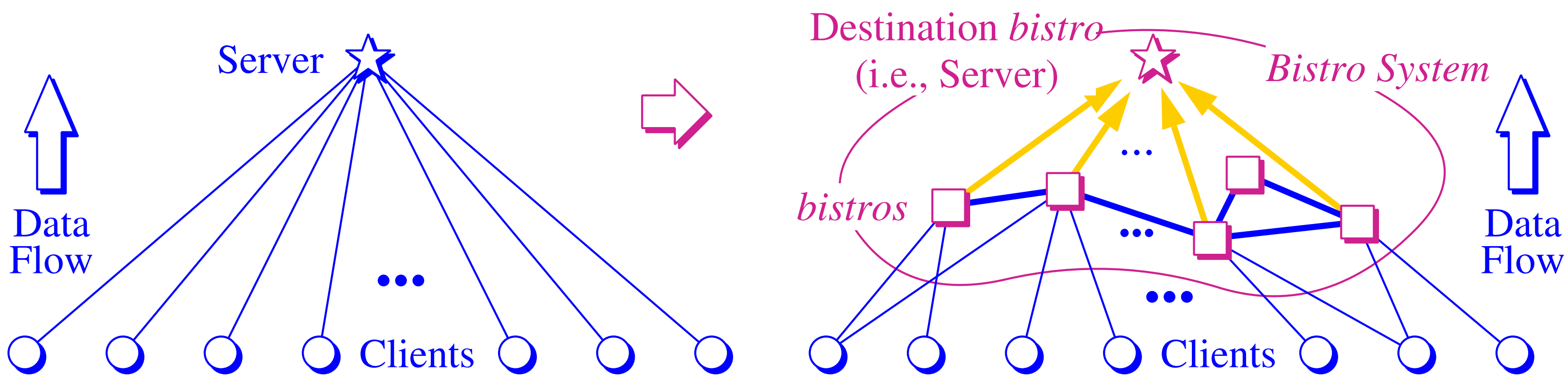
- A client generates a *fingerprint* for the document (tax return)
- Destination *bistro* issues a *timestamped* and *certified e-ticket*

A Solution to *Upload* with *Deadlines*



- **Real-time timestamp**
- **Step 2: Low-latency upload to *any* intermediary (commit) *(client-push)***
  - **A client *verifies* the *digital signature* on the *e-ticket*, *encrypts* the document, and upload the *encrypted document* to any *bistro* (or a designated bistro for a tax partner)**

A Solution to *Upload* with *Deadlines*

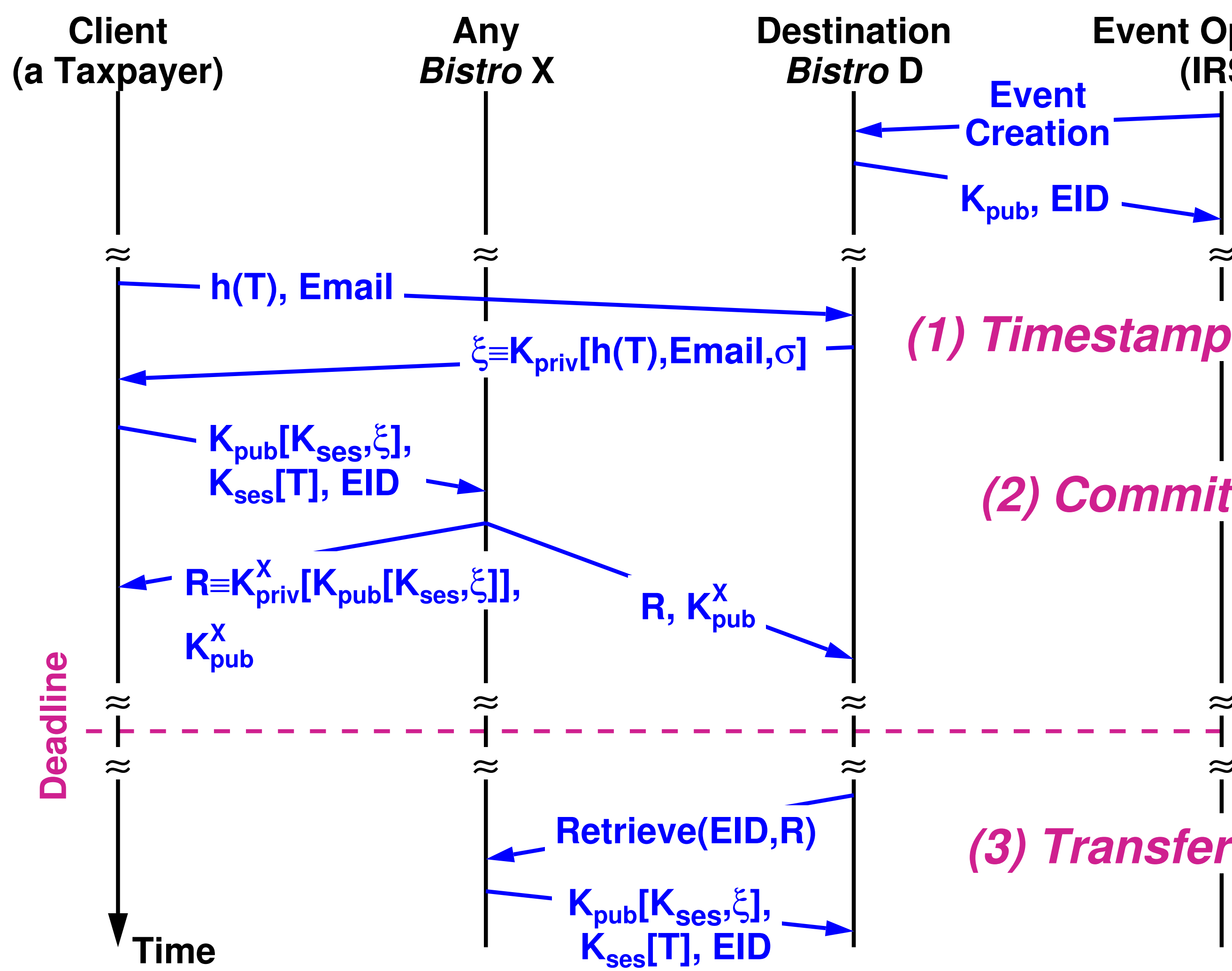


(a) upload without *Bistro*

(b) upload with the *Bistro System* after *Bistro* software is installed on the Server

- **Step 1: Real-time fingerprinting & timestamp**
- **Step 2: Low-latency upload to *any* intermediary (commit) *(client-push)***
- **Step 3: Timely transfer to final destination *(large scale data transfer)* *(server pull)***

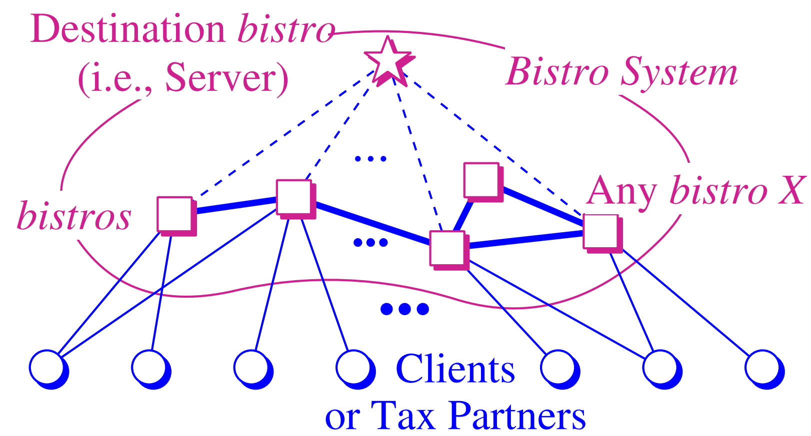
Bistro Protocol Summary [Cheng01a]



***Legend*:**

EID :	Event ID
K_{pub} :	Event Public Key
K_{priv} :	Event Private Key
K^X_{pub} :	*Bistro* X Public Key
K^X_{priv} :	*Bistro* X Private Key
T :	Data to upload
h() :	Message Digest
σ :	Timestamp
ξ :	Ticket
R :	Receipt
K[ ] :	Encryption

Who is Trusted with What?



- **Event Operator (IRS)**
  - **trusts the Destination *Bistro* for *this* event**
- **End User (tax payer)**
  - **trusts its Client software**
  - **trusts the Destination *Bistro* for *this* event**

analog to certified mail with untrusted post-office

- **Destination *Bistro***
  - **trusts the Bistro software to generate a pair of public and private keys (K_{pub}, K_{priv}) for *this* event**

Bistro FAQ

Why do you need step (2)? Why can't the destination server get the document directly from a client in step (3)?

- A client can be behind a firewall or a client's machine can be turned off.
- A *bistro* is always on the public Internet, and may be subject to attacks. Therefore, all documents on a *bistro* must be encrypted.

Why did you show that step (2) is done before the deadline?

- Step (2) is the *commit* step, it does not need to be done before the deadline since the only transaction that is required to be completed before the deadline is step (1). However, to complete a client's transaction (so that the client can leave or shutdown its PC), we must push the encrypted data out of the client's PC.
- Since there can be many *bistros*, this will not cause a traffic jam. Also, most of the data transfers during this step are localized.

Bistro FAQ (Cont...)

Can a fingerprint be forged?

- ***SHA1*** is the state-of-the-art electronic fingerprinting algorithm. It generates a 160-bit fingerprint for an any-size document. If you modify a single bit in a document, the new document has a completely different fingerprint. There is no known algorithm that can forge a SHA1 fingerprint while maintaining the integrity of a document.

Can the destination server be under denial-of-service attack?

- Yes. That's one weakness of the Internet. However, you can setup ***mirrors*** for the destination server by copying the ***credentials*** of the destination server onto alternative servers. Nevertheless, in the current *Bistro* system, this needs to be done ahead of time.

How secure is the encryption? Can it be cracked?

- The strength of encryption is usual a function of the ***algorithm*** and ***key size***. The *Bistro* system is not tied to a particular algorithm or key size. It lets the event operator choose these at the time an event is setup. As new and more secure algorithms become available, the system will need to be upgraded to support them.

Bistro FAQ (Cont...)

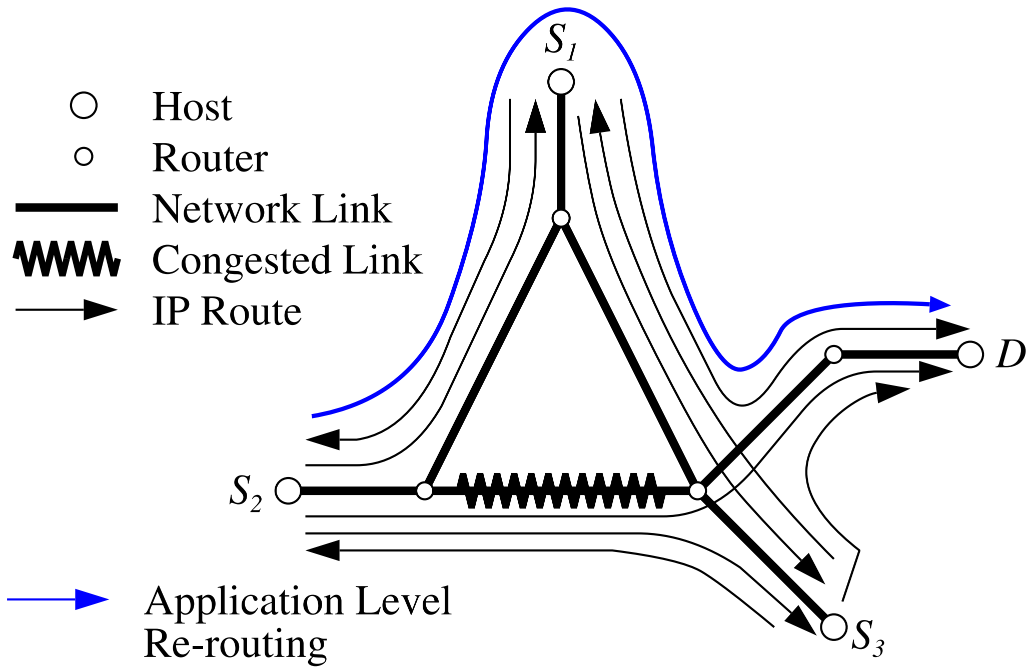
How big a server do we need in order to give out so many timestamped and certified e-tickets in a short period of time?

- To certify an e-ticket requires a digital signature, and signing digital signatures is a time consuming process. But, as it turns out, digital signatures can be ***batched***. We have developed ***batch signing schemes*** (please see our publications) to remove this limitation. Now we can sign as many as it comes.

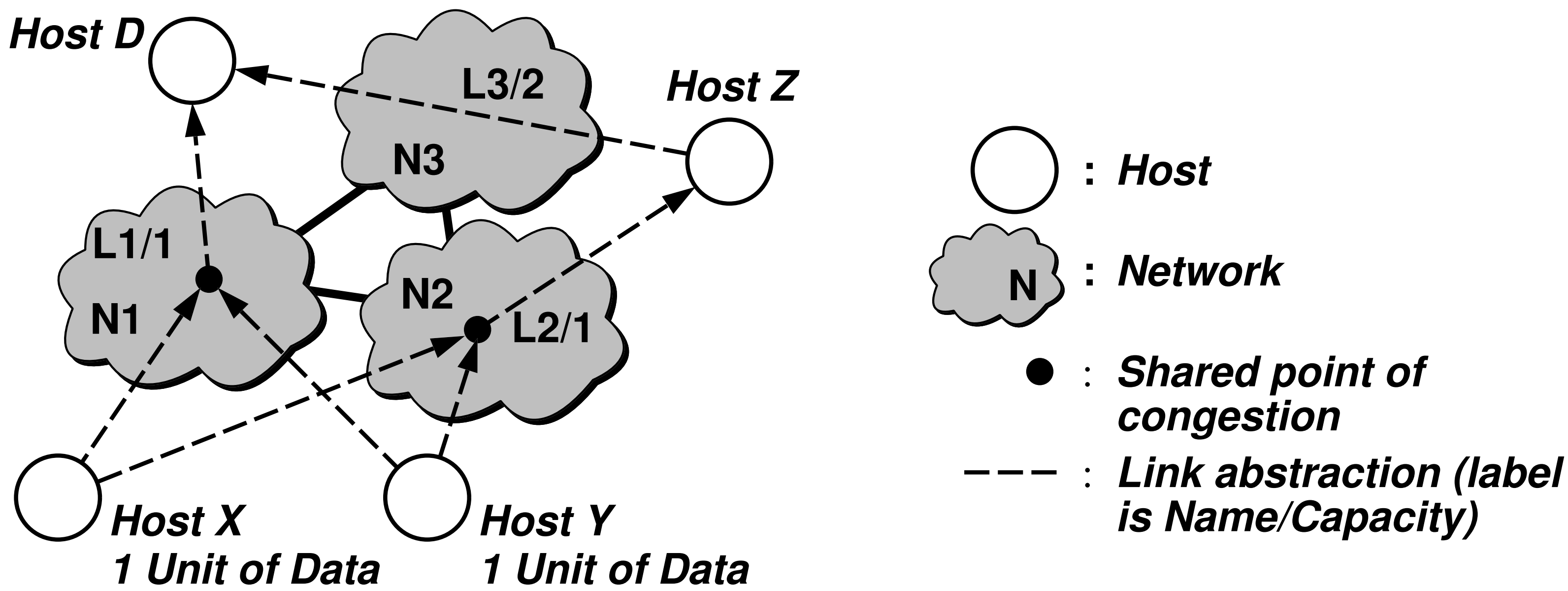
What about client authentication? Do we know, with certainty, who is submitting a tax return?

- As in the current system, you do not know who is submitting a tax return at the time of submission. Even with paper submission, it is very difficult to verify a signature. ***Client authentication*** is outside the scope of the ***Bistro*** system.
- If a tax payer uses a tax partner's service to submit his/her tax return, it would be easy to authenticate a tax partner. Each tax partner can independently generate a pair of public and private keys (according to the specifications from IRS) and send the public key to IRS. Each submission can be digitally signed with the tax partner's private key. IRS can verify the digital signature using the corresponding public key.

Opportunities to Speed up Data Transfers



Opportunities to Speed up Data Transfers (Cont...)



Scenarios:

- X & Y send simultaneously to D -- 2 units of time
- X sends to D, then Y sends to D -- 2 units of time
- X & Y send simultaneously to Z then to D -- 3 units of time
- X sends to D // Y sends to Z then to D -- 1.5 units of time
- *??? -- 1.2 units of time*

Advantages of Bistro

- Shares resources and a *single* infrastructure
- Replaces a traditionally *synchronized client push* solution with a *non-synchronized* combination of *client-push* and *server-pull*
- Eliminates hot spots by spreading most of the demand on the server *over time*, by making the actual data transfer *independent* of the deadline
- Deployable *today*, i.e., no change required inside the network
- *Gradual* deployment over a public, private, or mixed infrastructure of hosts
- More *dynamic* and therefore more *adaptive* to system and network conditions

Vision

- A *bistro* in every administrative domain
  e.g., co-located with web servers or mail servers

- Entire network of *bistros* collects data for one application/agency one day and for another application/agency the next day

- Use the *Bistro* infrastructure for other large scale data gathering, transfer, and storage needs

CS551
Bistro Improvements

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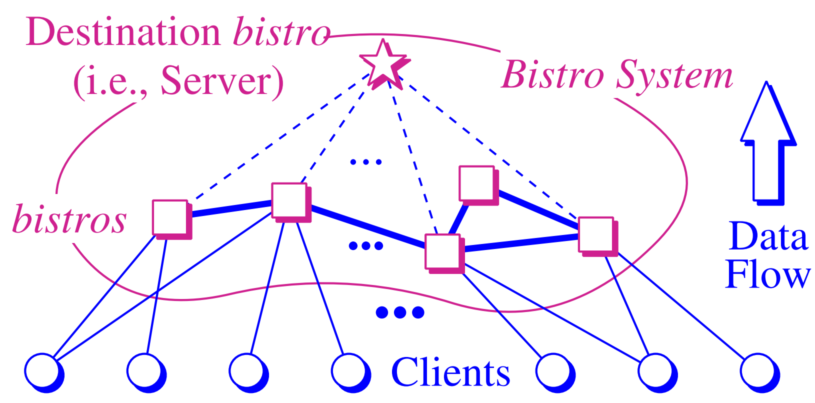
Some Research Problems

- **Resource location and discovery**
- **Placement and assignment**
- **Security**
- **Large scale data transfer**



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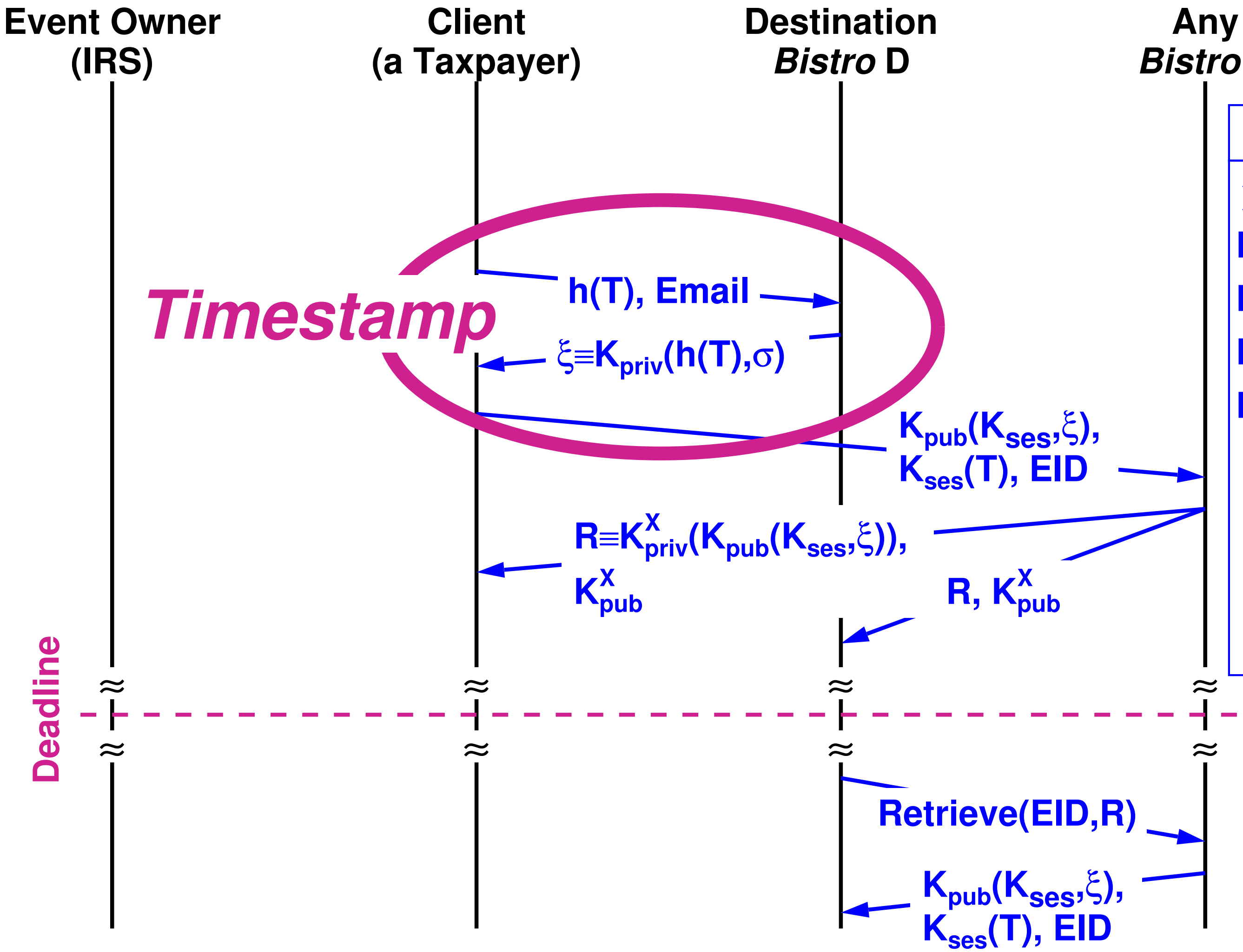
Bistro



***Legend*:**

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- **T** : Data to upload
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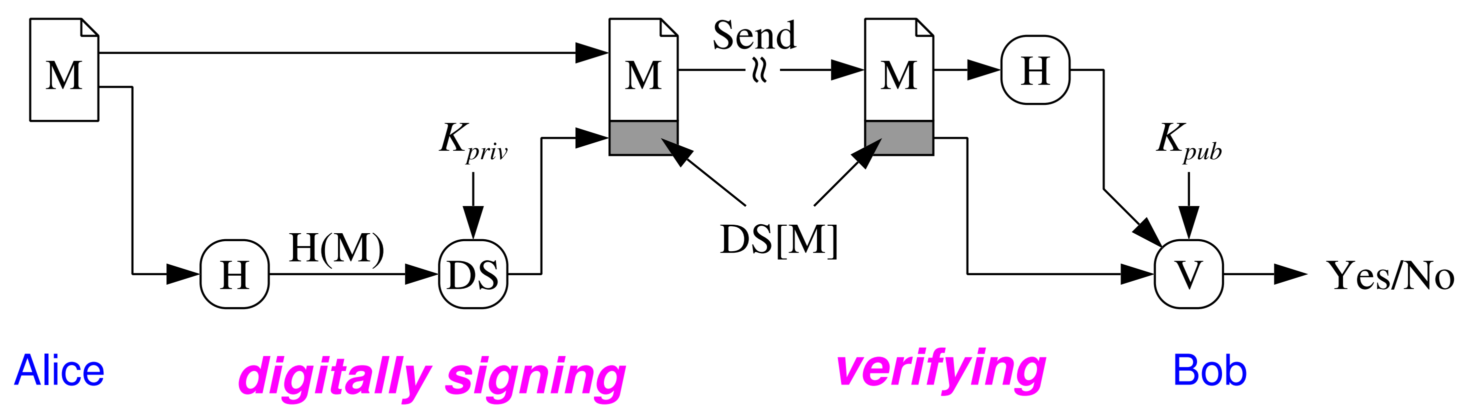
Online Digital Signatures

- Why digital signature?



- integrity
- authentication
- nonrepudiation

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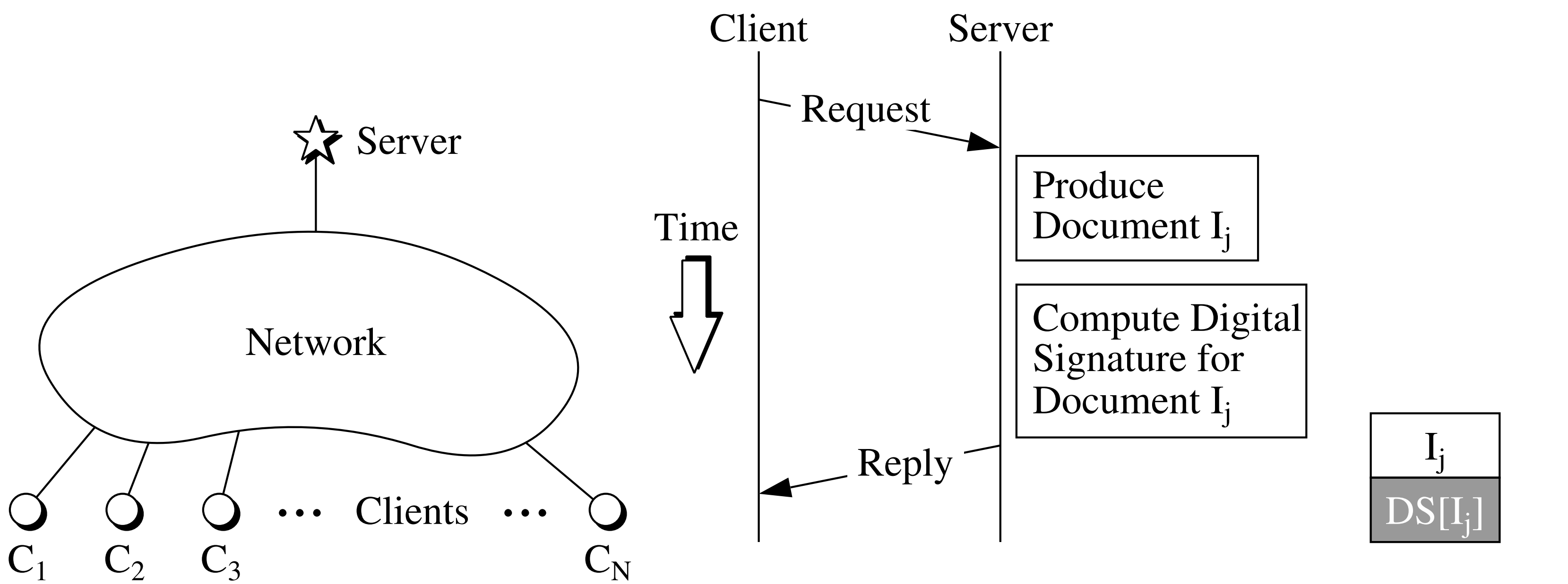
Real-Time Timestamp

- **Using digital signature to generate real-time timestamp**



(a) system

(b) basic service

(c) reply message sent to client j

- ***high cost of modular of arithmetic***

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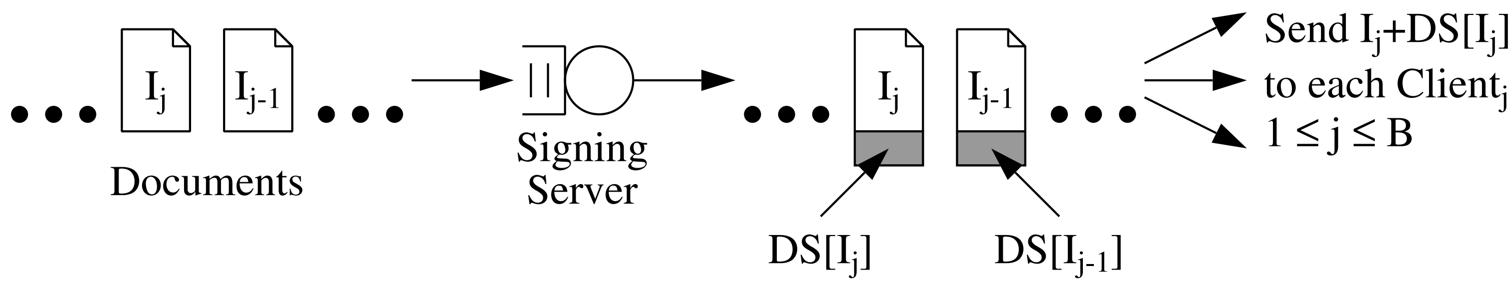
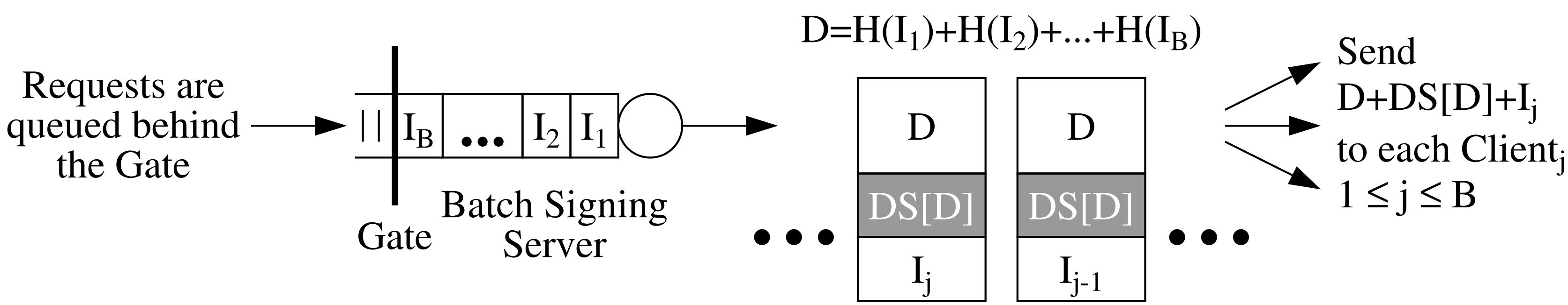
Our Approach

No batching scheme



Simple batching scheme



extra information to be sent to clients

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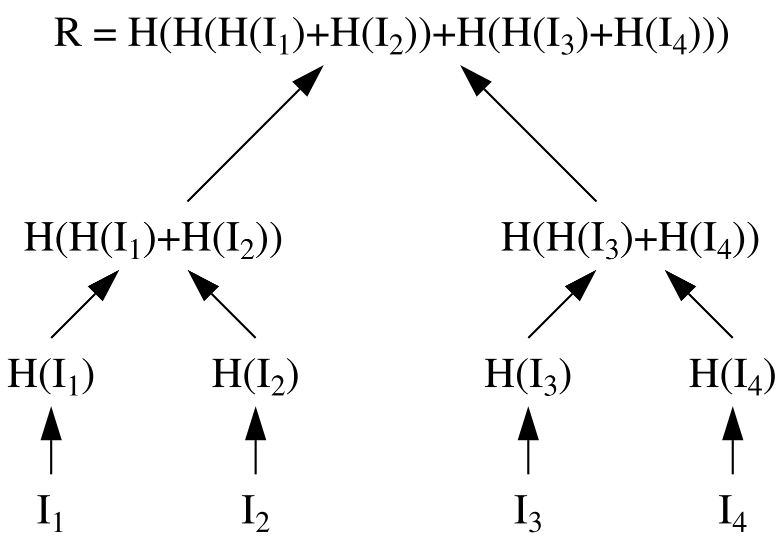
Our Approach (Cont...)

- **Tree-based batching scheme**



Send to C_1:

R
DS[R]
$H(I_2)$
$H(H(I_3)+H(I_4))$
I_1

Send to C_2:

R
DS[R]
$H(I_1)$
$H(H(I_3)+H(I_4))$
I_2

Send to C_3:

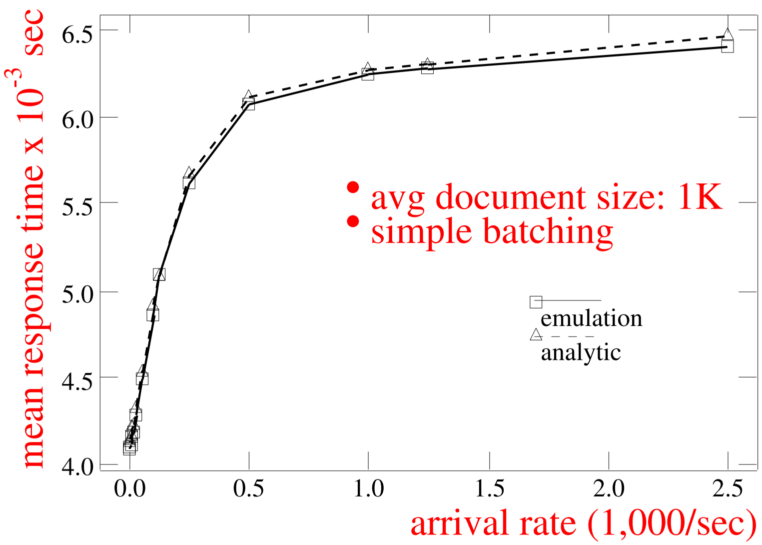
R
DS[R]
$H(I_4)$
$H(H(I_1)+H(I_2))$
I_3

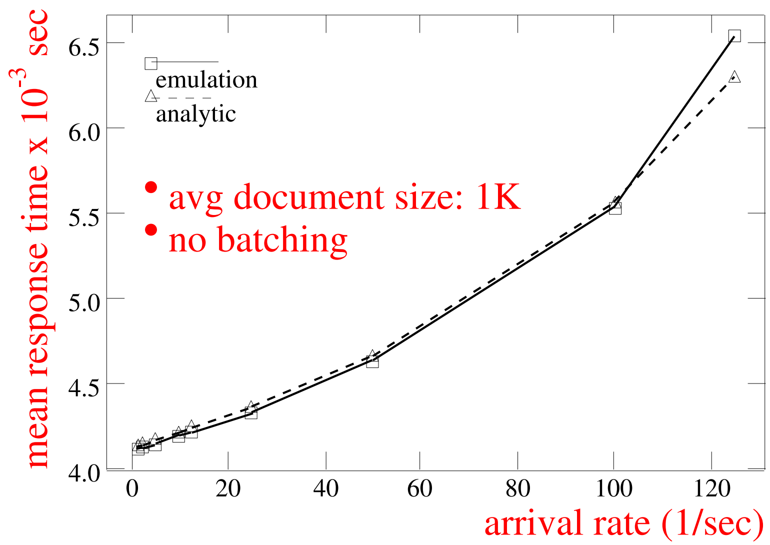
Send to C_4:

R
DS[R]
$H(I_3)$
$H(H(I_1)+H(I_2))$
I_4

Performance Evaluation

- Batch-based schemes do reduce a server's CPU load (where hashing is not the dominant factor)





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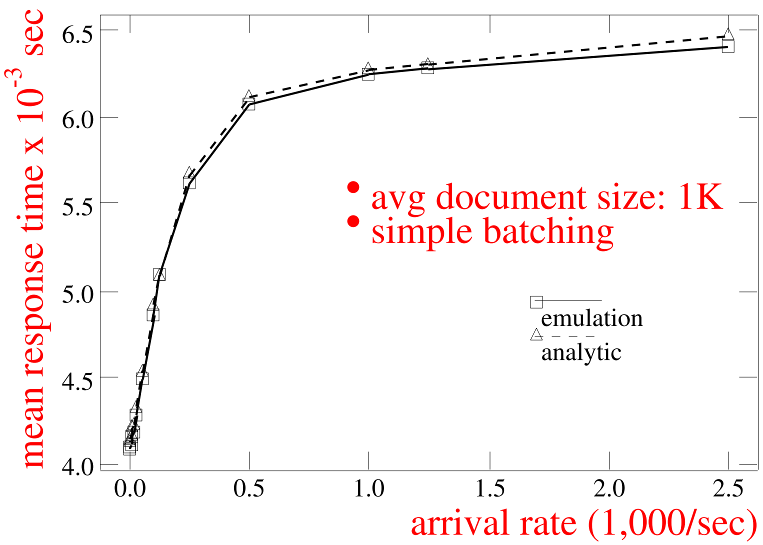
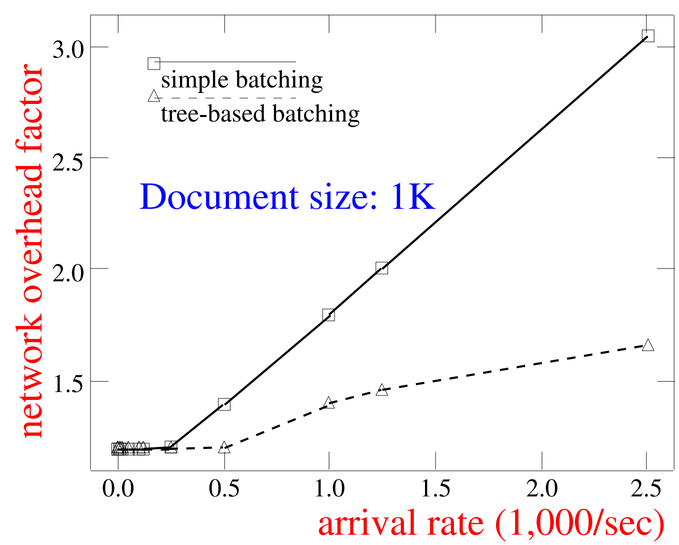
Performance Evaluation

- Batching schemes have considerable advantage but cost relatively little (where hashing is not the dominant factor)





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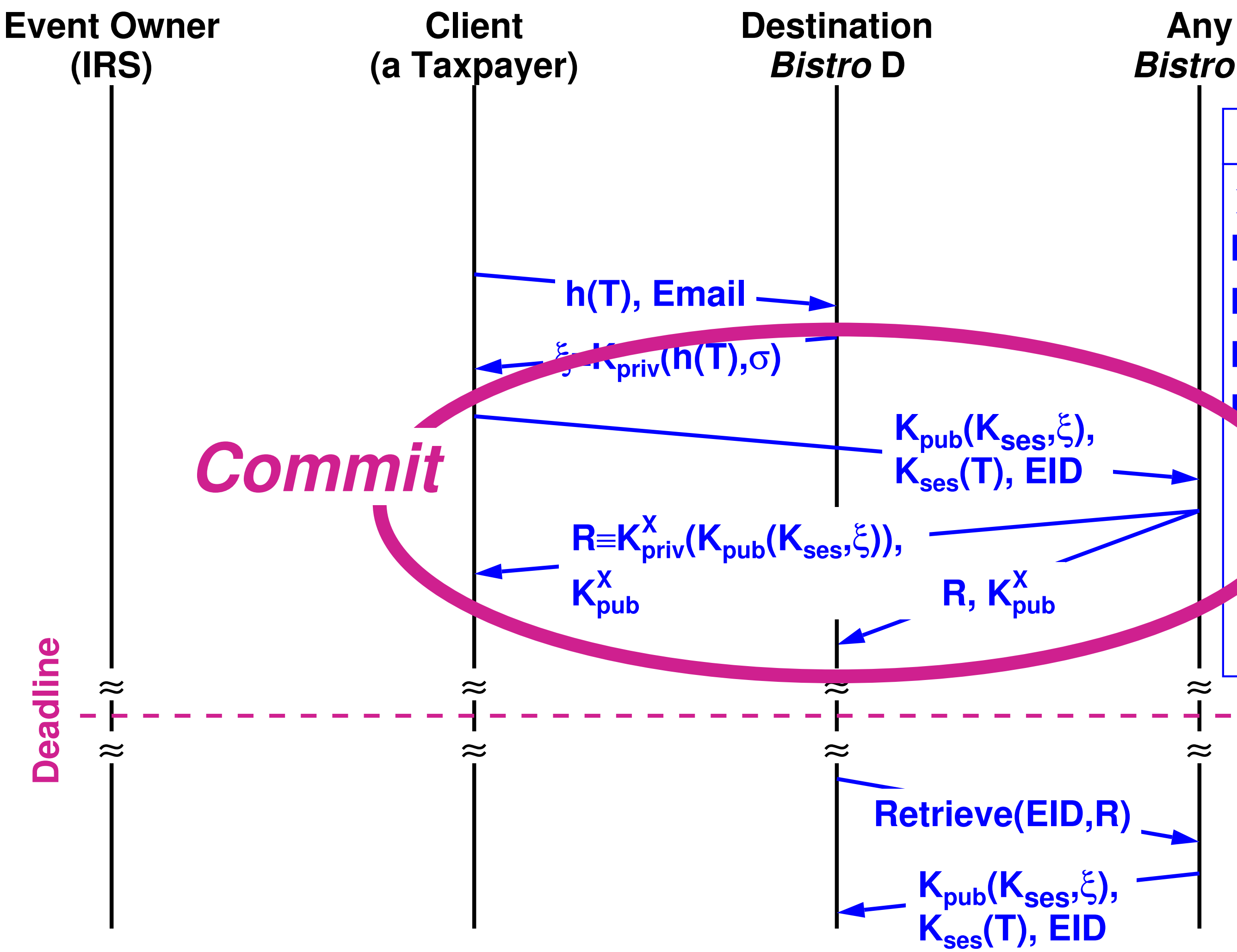
Bistro



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Commit Problem

Extreme Cases

- Final destination is the only *bistro*
- All hosts are *bistro*s
- Each organization has a local *bistro* (same granularity as NNTP servers, DNS servers, etc.); in this case commit problem still non-trivial if the local *bistro* is not part of the public Internet

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Commit Problem

Middle Ground

- Assignment problem
  - *bistro*s are fixed & the difficulty is in assigning clients to the *bistro*s

NP-complete
for several useful objective functions

- Placement or selection (plus assignment) problem
  - location of *bistro*s is flexible
  - choose *M* out of *N* *bistro*s as well as assign clients to chosen *bistro*s

- *Why is this different from downloads?*

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Performance Study

- **Simulation setup (using ns2 & GT-ITM)**
  - transit-stub graph with 152 nodes
  - 2 transit domains, with avg 4 nodes each, edge between pair of nodes with prob 0.6 & each node having 3 stub domains connected
  - stub domains have on avg 6 nodes each, edge between pair of nodes with prob 0.2
  - capacity of transit-transit edge is 1 Mbit/s
  - capacity of transit-stub or stub-stub edge is 256 Kbits/s
  - 96 simultaneous uploads with files unif. distr. between 100 KBytes & 2 MBytes
  - low background load (30%); high background load (70%)

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Performance Study

- **Note: *seq.* uploads to *single* server should be approx 3000 sec, and avg. transfer time of one client should be approx 33 sec**
- **Note: *simultaneous* uploads to *single* server takes approx 3000 sec, but avg. transfer time of one client takes approx 2000 sec**
- **Performance metrics used**
  - **mean transfer time over all clients**
  - **total (or maximum) transfer time**
- **Policies**
  - **random, ping-v, ping-m**
  - **unrealistic heuristic (approx. lower bound)**

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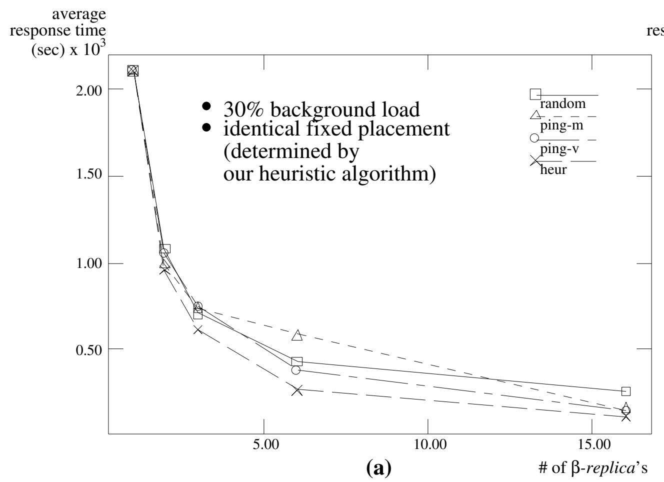
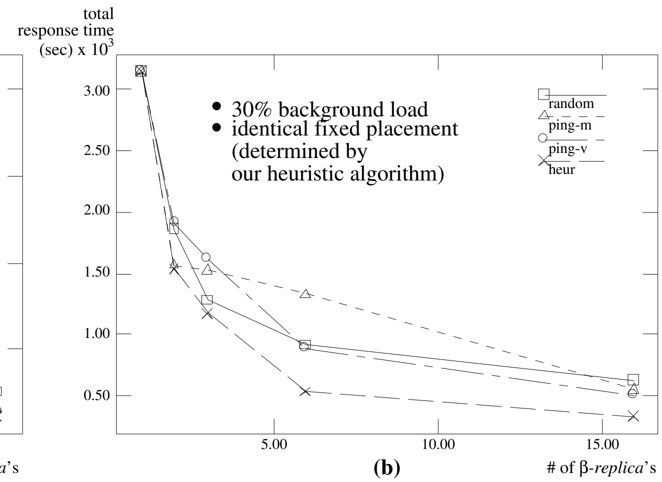
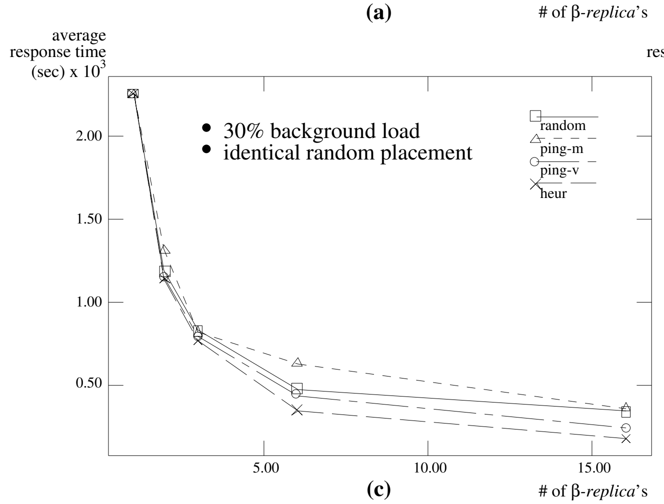
Performance Results



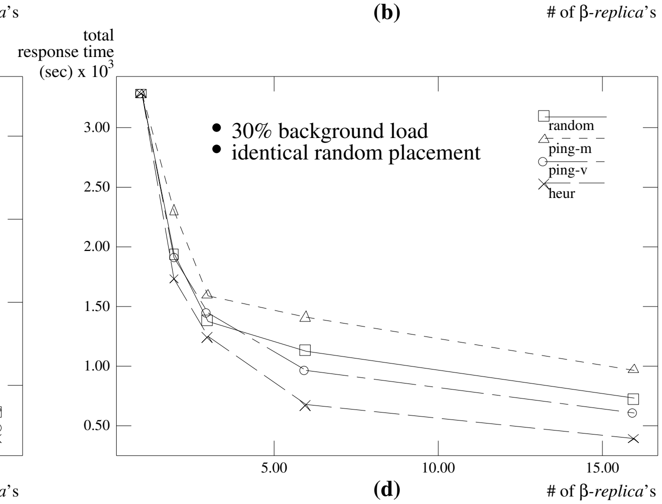
(a)



(b)



(c)



(d)

Performance gains mainly due to parallelism

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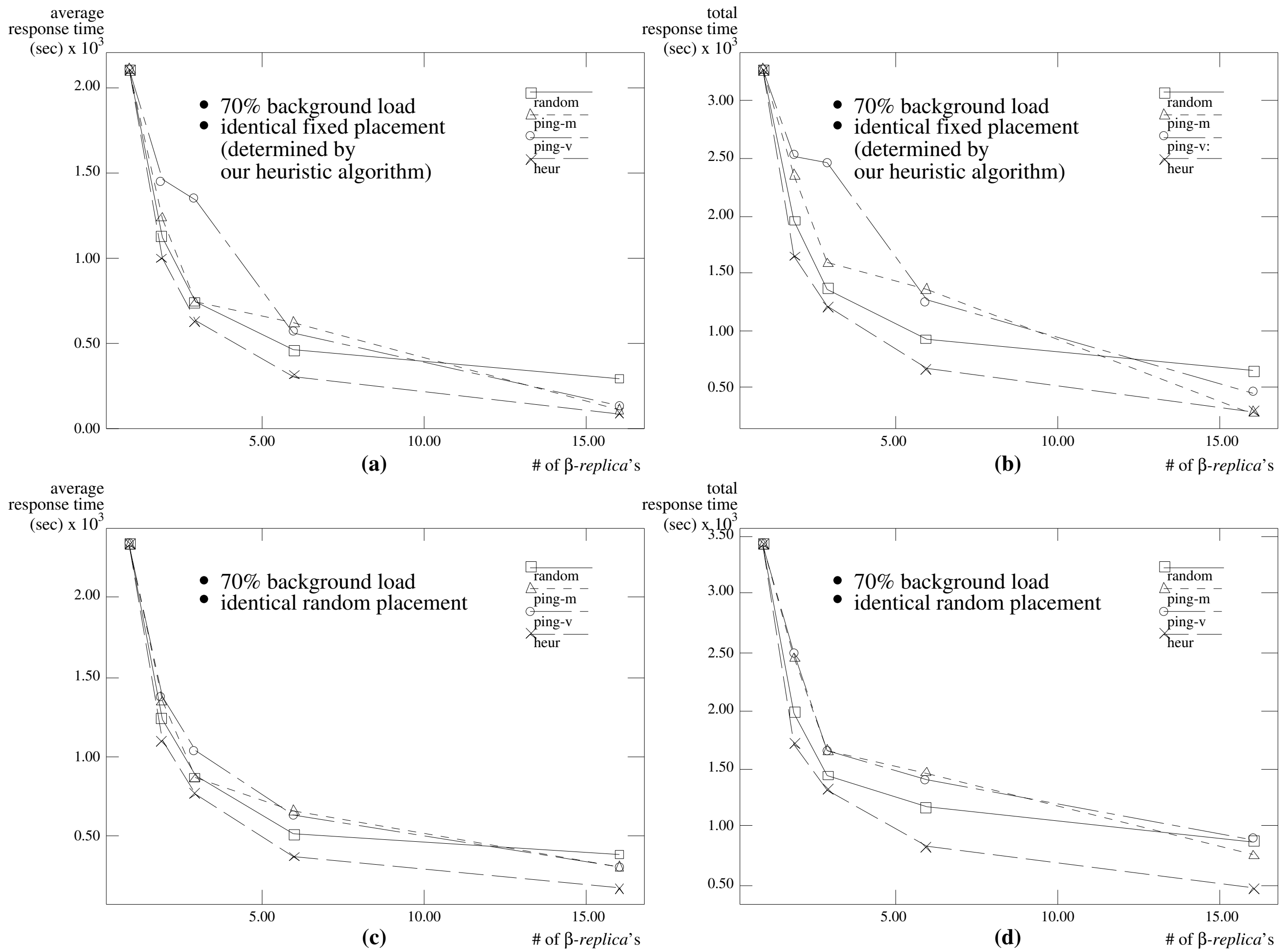
Performance Results



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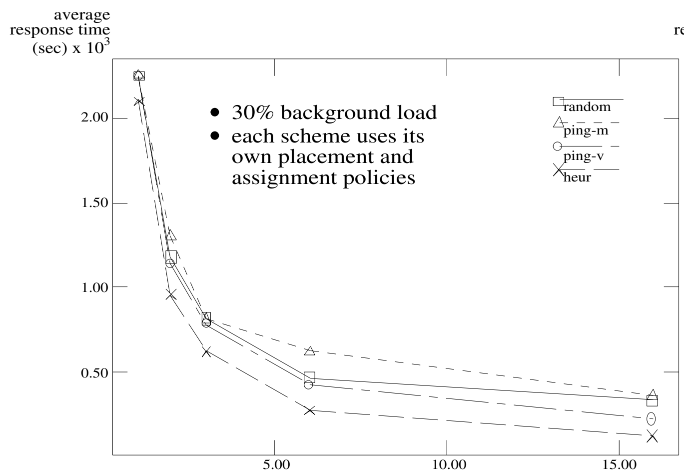

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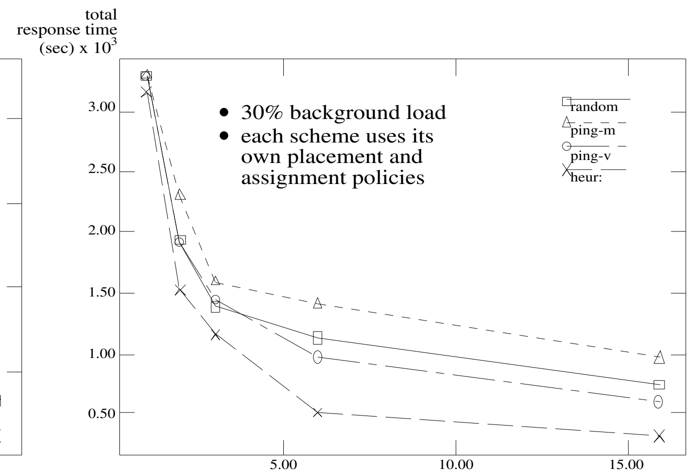
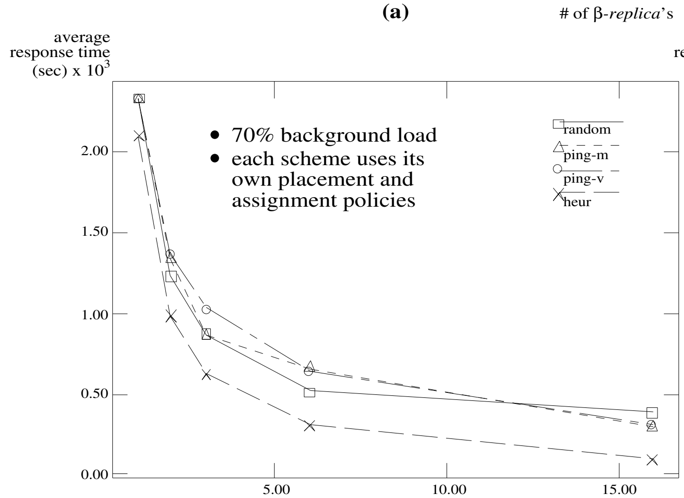
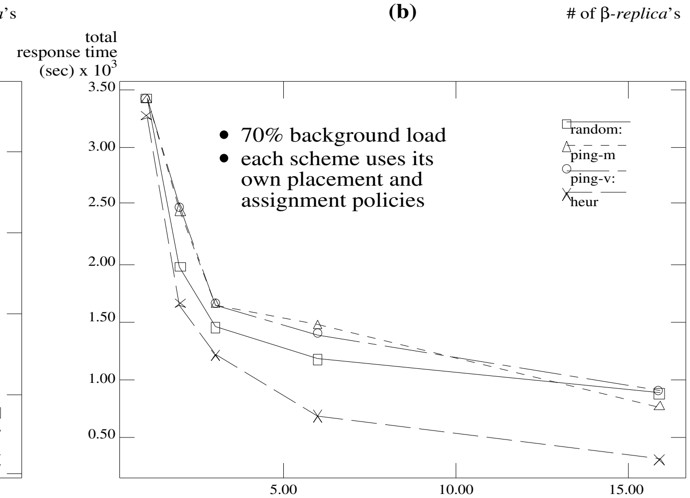


(b)



(c)



(d)

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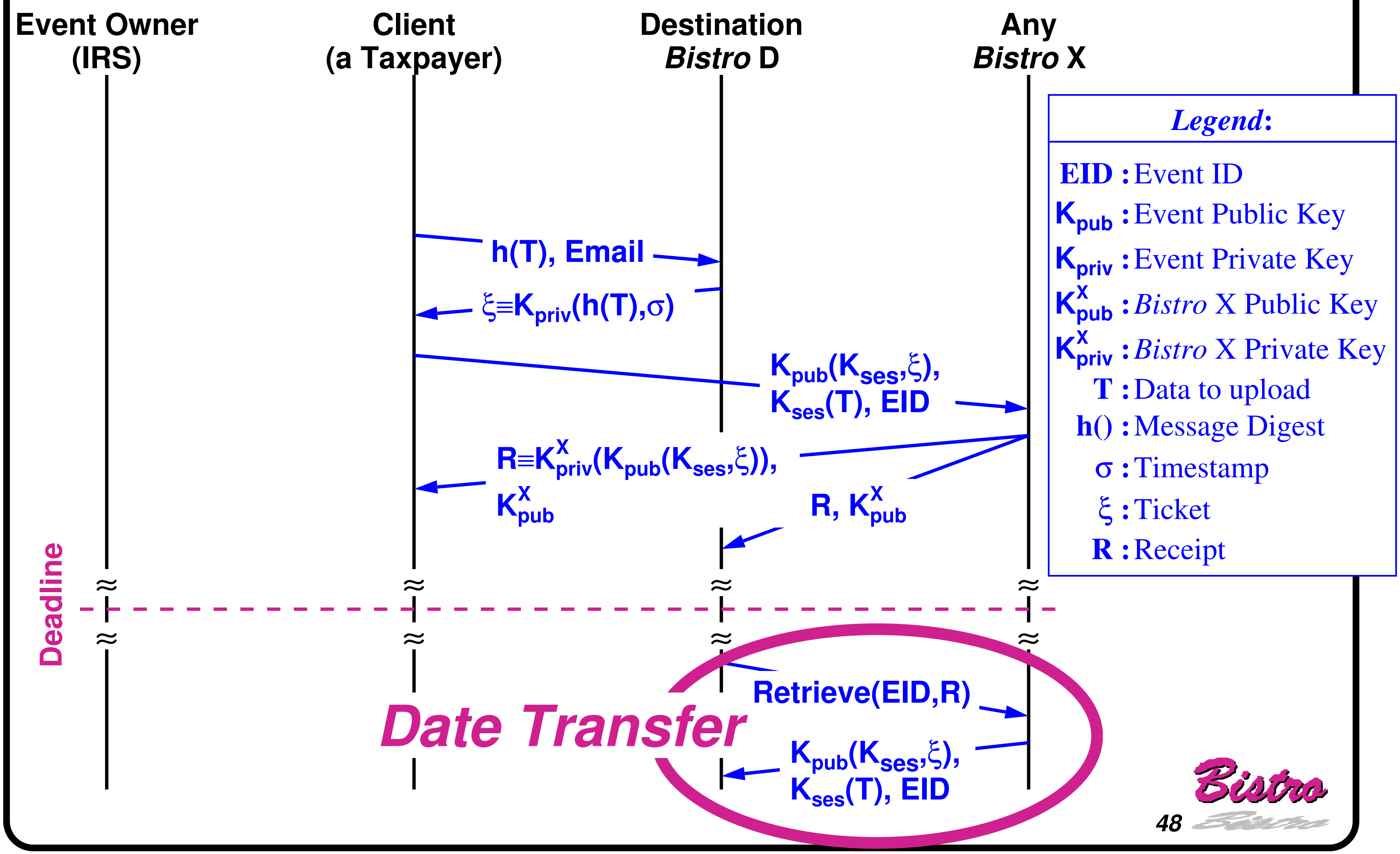
Bistro



Bistro

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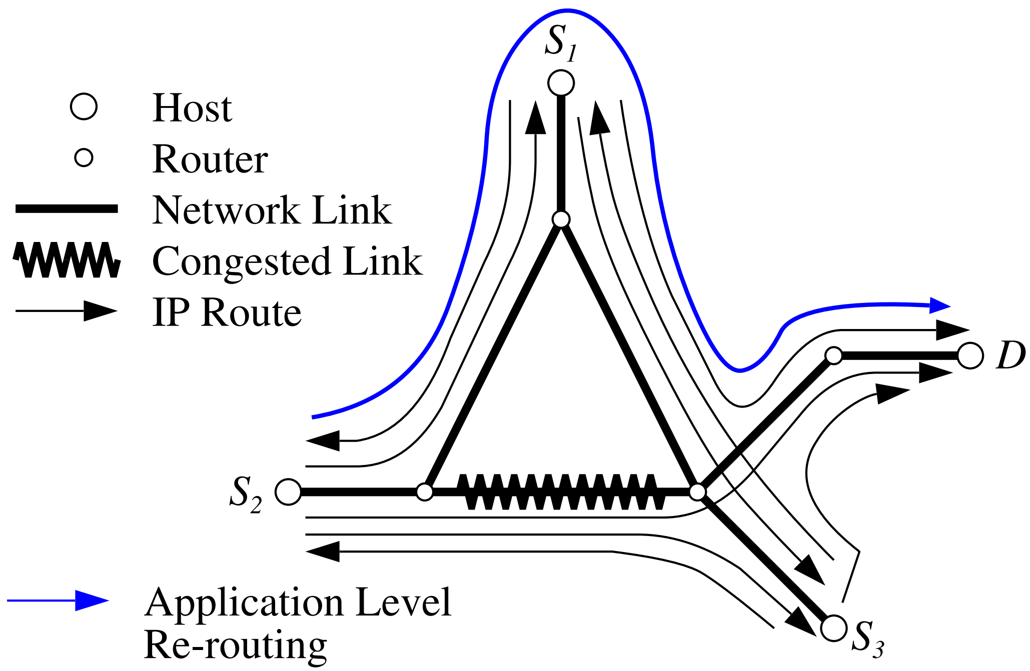
Large-scale Data Collection

- Destination server needs to collect data from all other *bistros* but how?
- Several simple approaches
  - one-by-one — *poor resource utilization due to non-shared bottleneck link*
  - all-at-once — *longer transfer time*
  - spread-in-time-GT
  - concurrent-G

  network congestion
- *application level re-routing*
  - avoid congested links
  - devise a *coordinated* transfer schedule

Opportunities



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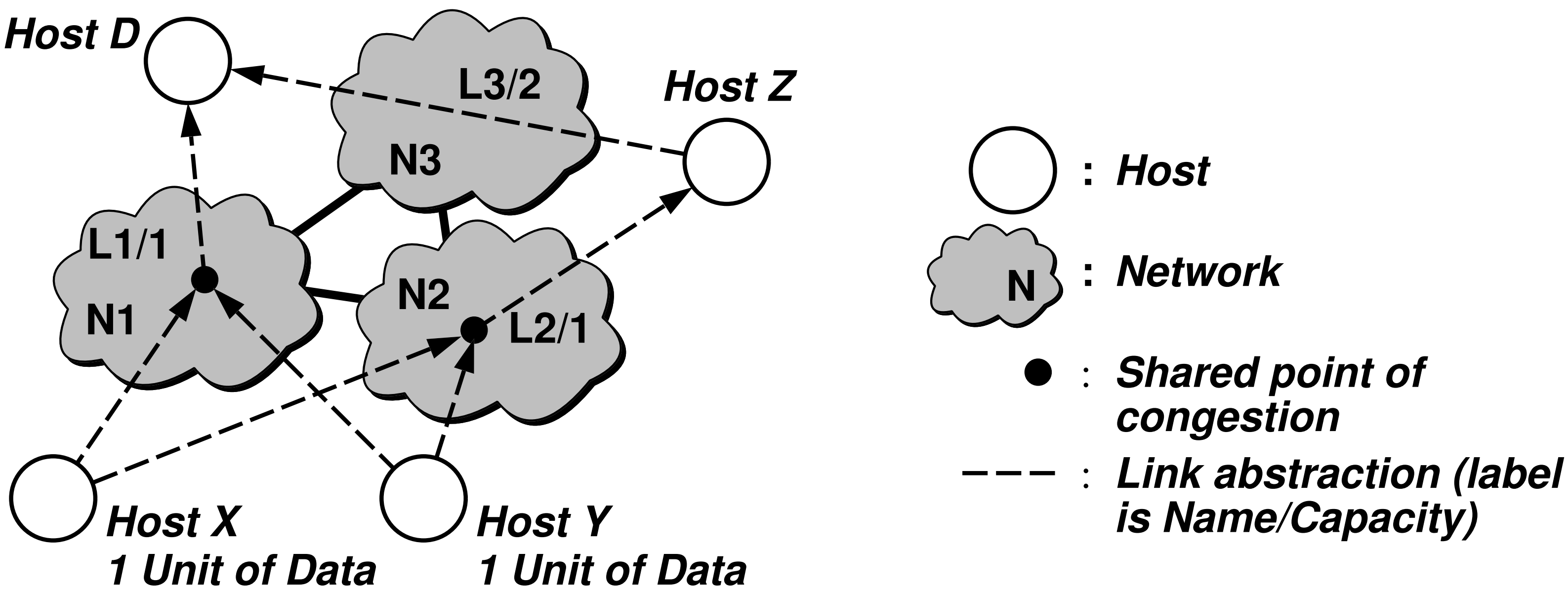
Opportunities (Cont...)



Scenarios:

- X & Y send simultaneously to D -- 2 units of time
- X sends to D, then Y sends to D -- 2 units of time
- X & Y send simultaneously to Z then to D -- 3 units of time
- X sends to D // Y sends to Z then to D -- 1.5 units of time
- *??? -- 1.2 units of time*

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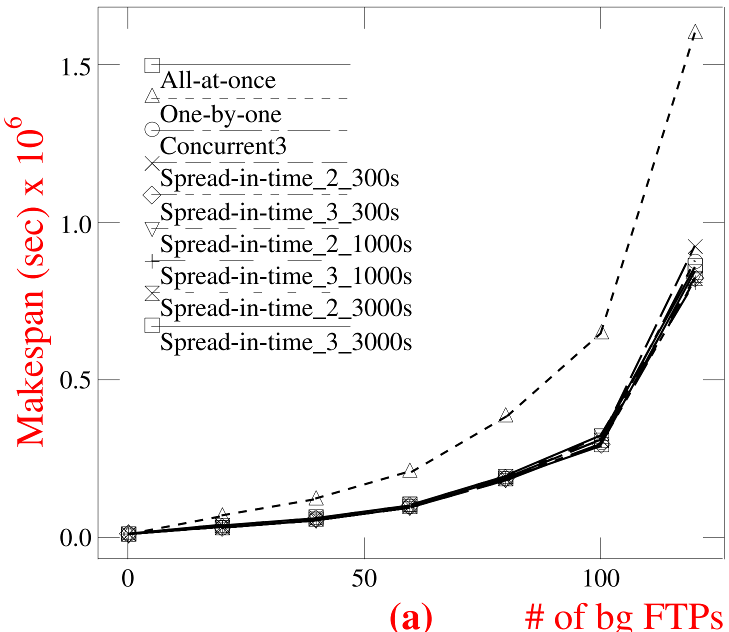
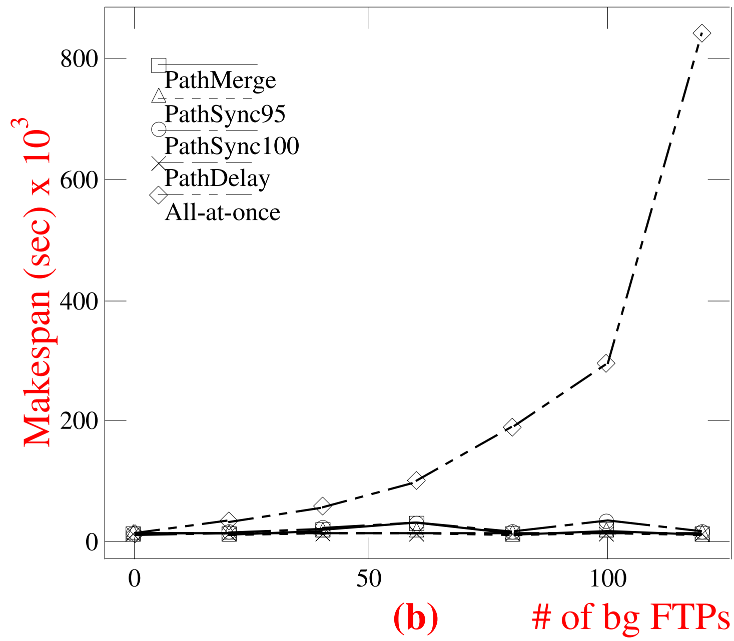
Transfer To Destination

- Simulation setup (using ns2 & GT-ITM)
  - 7 other bistros, each with a total amount of data unif. distr. between 25 MBytes & 75 MBytes and the total amount of data in *bistros* is 350 MBytes.





- Performance improvement due to rerouting around congestion

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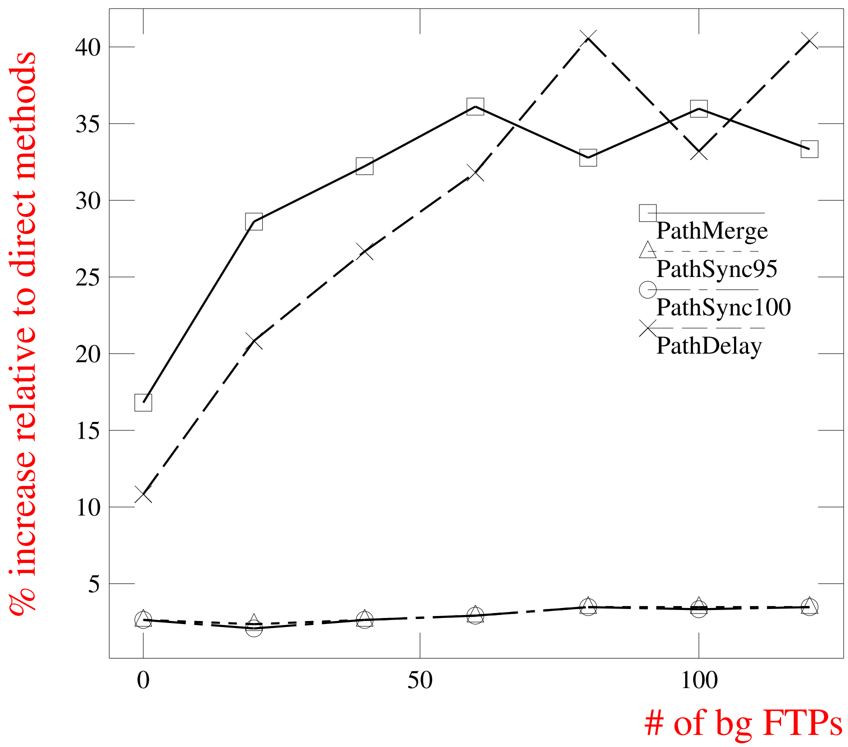
Storage Space Requirements



- **needs fairly little additional storage space**

  pathsync < 4%, pathmerge and pathdelay < 41%

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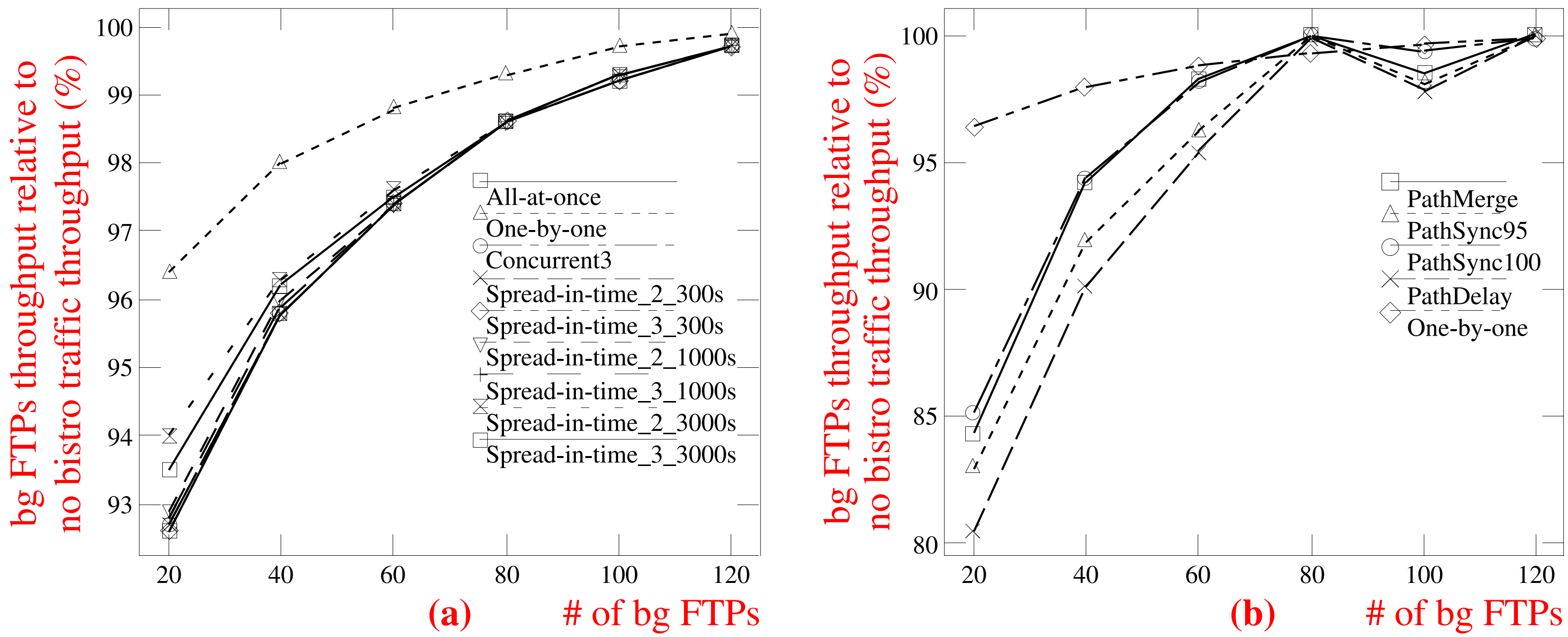
Effect on Other Traffic



- **no significant effect on throughput of other traffic**

(< 17%)

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Contributions Thus Far

- First effort to study many-to-one communication problem at the *application* layer & attempt at stating fundamental obstacles
- Proposed a reasonably general framework
- Proposed solutions to all parts of the problem
- Suggested some open problems

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Related Work

- Akamai and other content distribution networks
- Napster
- A variety of server selection problems
- Internet security

Related Work (Cont...)

- **Many-to-one communication at IP level & within Active network framework**
  - Gathercast [Badrinath & Sudame 98]
  - Concast [Calvert et al. 00]
- **Wide area applications**
  - wide-area download applications: e.g., Akamai [Karger et al. 97]
  - Napster type systems, e.g., [Kong & Ghosal 99]
  - application layer multicast: e.g., [Chu et al. 00]
- **Client-side server selection**
  - statistical: e.g., [Seshnm et al. 97]
  - dynamic: e.g., [Carter & Crovella 97] [Sayal et al. 98] [Dykes et al. 00]

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Related Work (Cont...)

- **Application level re-routing**
  - alternate paths [Savage et al. 99]
  - Detour [Savage et al. 99]
  - RON: resilient overlay network [Andersen et al. 01]

- **Online batch-based digital signature schemes**
  - modification on cryptographic algorithm [A. Fiat 89]
  - one-time signatures used in secret key system [Lamport 79, Merkle 88]

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Vision

- A *bistro* in every administrative domain
  e.g., co-located with web servers
- Entire network of *bistros* collects data for one application one day and for another application the next day
- Use the *Bistro* infrastructure for other large scale data gathering, transfer, and storage needs

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