Delay Tolerant Bulk Data Transfers on the Internet (2009)

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Overview of Presentation

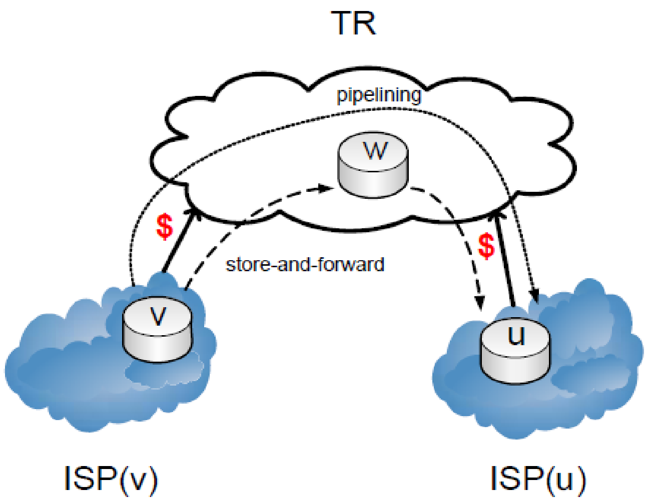
- Introduction
- Background
- Transfer Policies & Performances
- SnF VS. Courier Service
- Related Work
- Conclusions
- Question & Discussion

Introduction

- What is Delay Tolerant Bulk (DTB) Data Transfer
    - Large Hadron Collider
    - Beijing Olympic Games
- Why research in this area
    - Expensive dedicated network
    - Inconvenient postal system
- How to do …

Background

- Network Model
  - Internet Service Provider (ISP)
  - Sender, ISP(v); Receiver, ISP(u)
  - Transit Storage Node w
- 95-percentile Pricing Scheme



Let x denote a time series containing 5-minute transfer volumes between a customer and a transit provider.

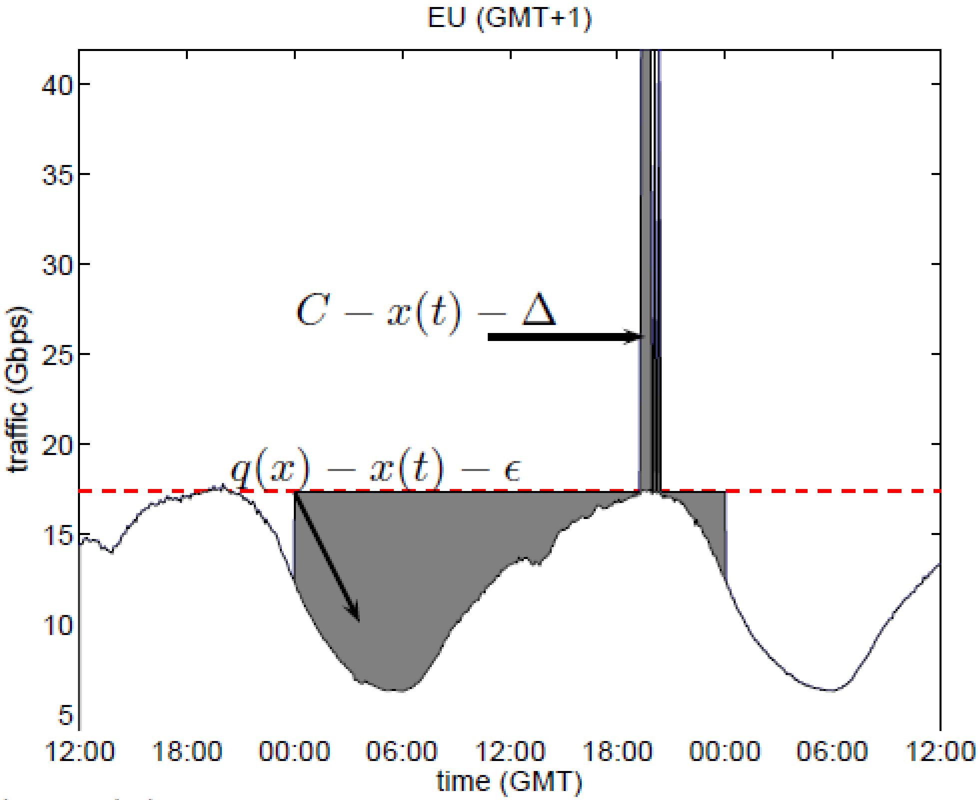
Customers pay an amount given by a charging function *that takes as input the charged volume q(x) defined to be the 95-percentile value of x.*

Introduction

- Two Transfer Policies
  - End-to-End Scheduling Policy (E2E-Sched)
  - Storage-and-Forward Policy (SnF)
- Researcher's Strategy (max free volume F; send volume B)
  - If B < F(E2E-Sched), then E2E-Sched can send them for free
  - If F(E2E-Sched) < B < F(SnF) and the gap is wide enough, SnF can utilize network storage to send the data at zero transit cost
  - If B > F(SnF), SnF can utilize network storage to send the data at the smallest possible transit cost

Background

- Off-peak Transmission Capacity
  - Link Capacity C
  - Background Traffic x
  - Charged Volume q(x)
  - ϵ, Δ are set to 0
- Water-filling Strategy



$$F(C, x, t_0, T) = \sum_{t=t_0}^{t_0+T-1} f(C, x, t)$$

$$f(C, x, t) = \begin{cases} q(x) - x(t) - \epsilon, & \text{if} \quad x(t) < q(x) \\ C - x(t) - \Delta, & \text{o.w.} \end{cases}$$

Transfer Policies

- E2E-Sched
  - A transfer policy employing source scheduling at the sender to regulate the amount of DTB traffic that is sent to the received at each 5-minute slot over an end-to-end connection.
  - Free capacity: $$F(\text{E2E-Sched}) = \sum_{t=t_0}^{t_0+T-1} \min\Big(f(C_v, x_v, t), f(C_u, x_u, t)\Big)$$
- SnF
  - A store-and-forward policy that first uploads data from the sender v to the transit storage node w within TR, and then pushes them from w towards the final receiver u

Transfer Policies

- Free Capacity F(SnF)
  - Simple iteration starting with F(SnF, t_0) = 0
  - $F(\mathrm{SnF}, t) = F(\mathrm{SnF}, t-1) + f(t), \quad t_0 \le t < T$
  - $$f(t) = \begin{cases} f(C_u, x_u, t), \text{ if } \; f(C_u, x_u, t) < f(C_v, x_v, t) \\ f(C_v, x_v, t) + \min(f(C_u, x_u, t) - f(C_v, x_v, t), b_w(t-1)), \\ \qquad \text{o.w.} \end{cases}$$

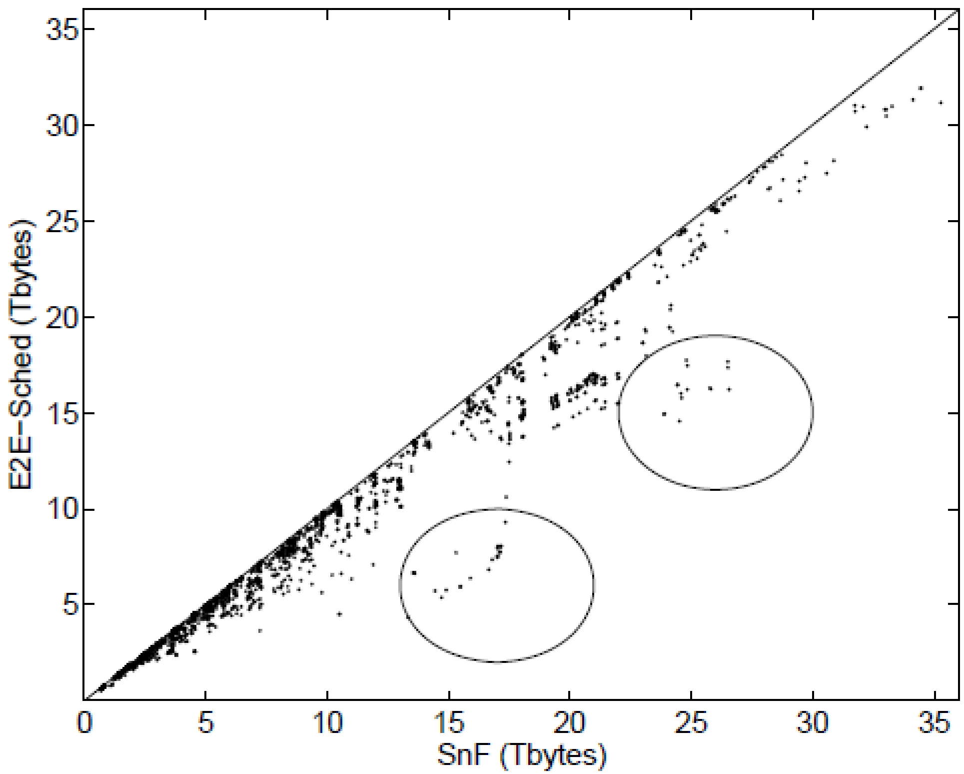
$$b_w(t) = \begin{cases} b_w(t-1) + f(C_v, x_v, t) - f(C_u, x_u, t), \\ \qquad \text{if } \; f(C_v, x_v, t) > f(C_u, x_u, t) \\ b_w(t-1) - \min(f(C_u, x_u, t) - f(C_v, x_v, t), b_w(t-1)), \\ \qquad \text{o.w.} \end{cases}$$

Performance

- Deadline T to 1 day (because of 24 hours period)
- Load time series x_v, x_u; Capacities C_v, C_u
- 280 links with capacity higher than 1Gbps from dataset
- The results showed:
  - a) Daily free volume, E2E-Sched, SnF
  - b) Free volume ratio vs time-zone difference
  - c) Free volume ratio vs dissimilarity (between each pair)

Performance

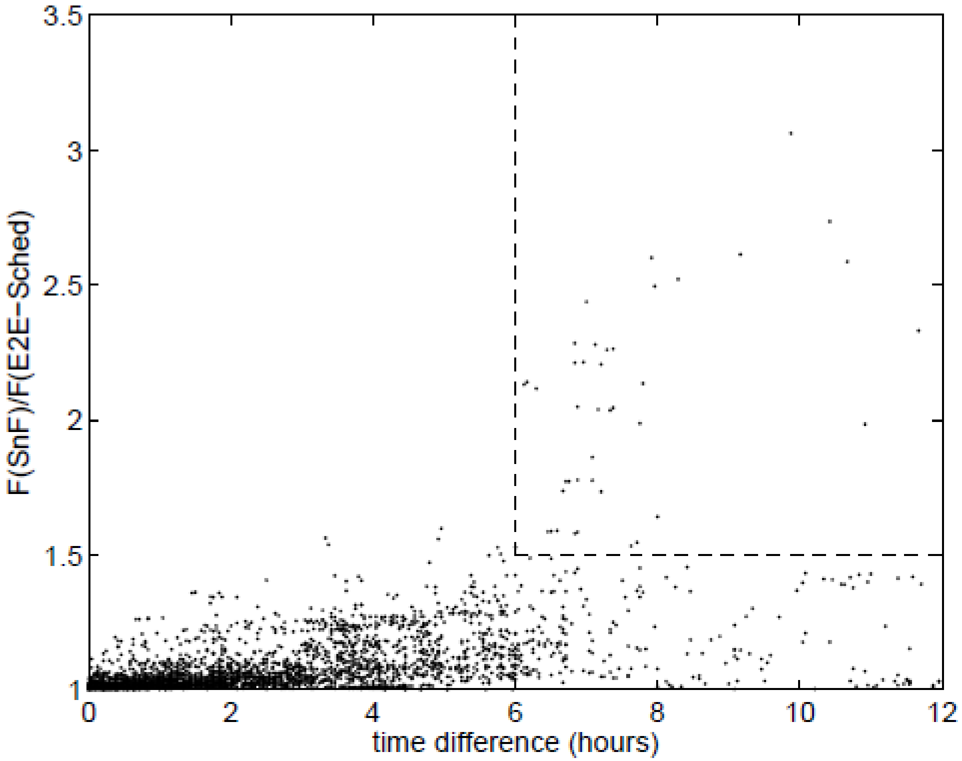
- 10-25 Tbytes
- Most of pairs are closely below the 100%-diagonal
- Several cases diverge



(a) Daily free volume, E2E-Sched, SnF.

Performance

- *the performance gain of store-and-forward increases with the appearance of non-coinciding off-peak hours, which in turn correlates with large time-zone difference.*

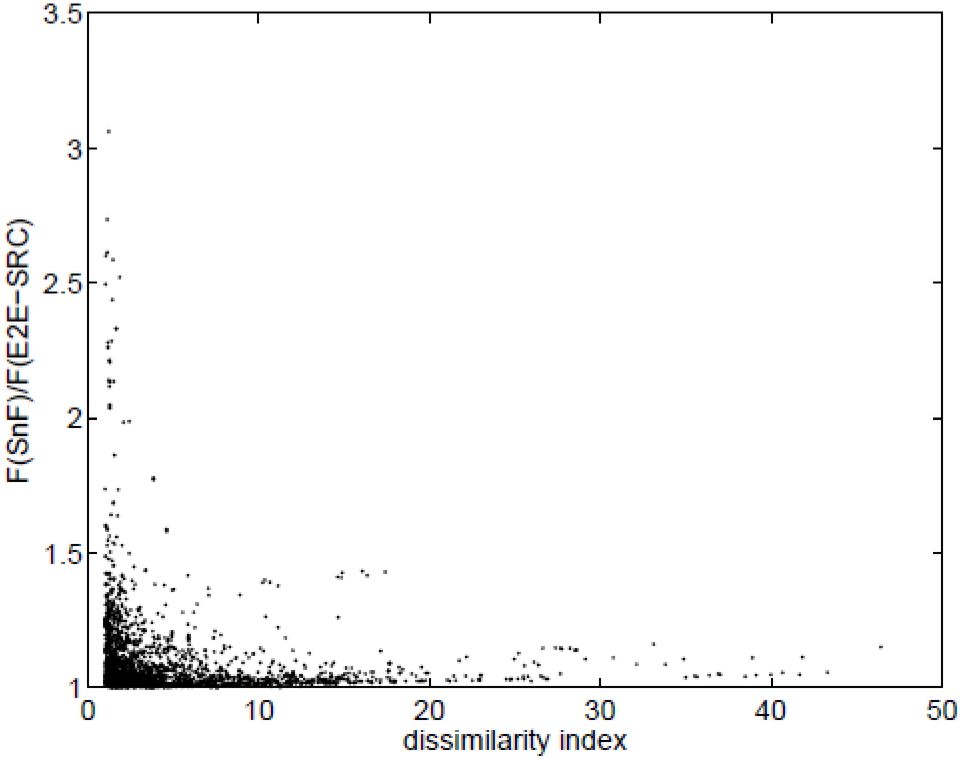


(b) Free volume ratio vs time-zone diff.

Performance

- *The figure shows that high ratios occur with dissimilarity close to 1.*

- *In the case of TR store-and forward becomes worthwhile in pairs of similar capacity and utilization that have at least 5 hours of time-zone difference.*



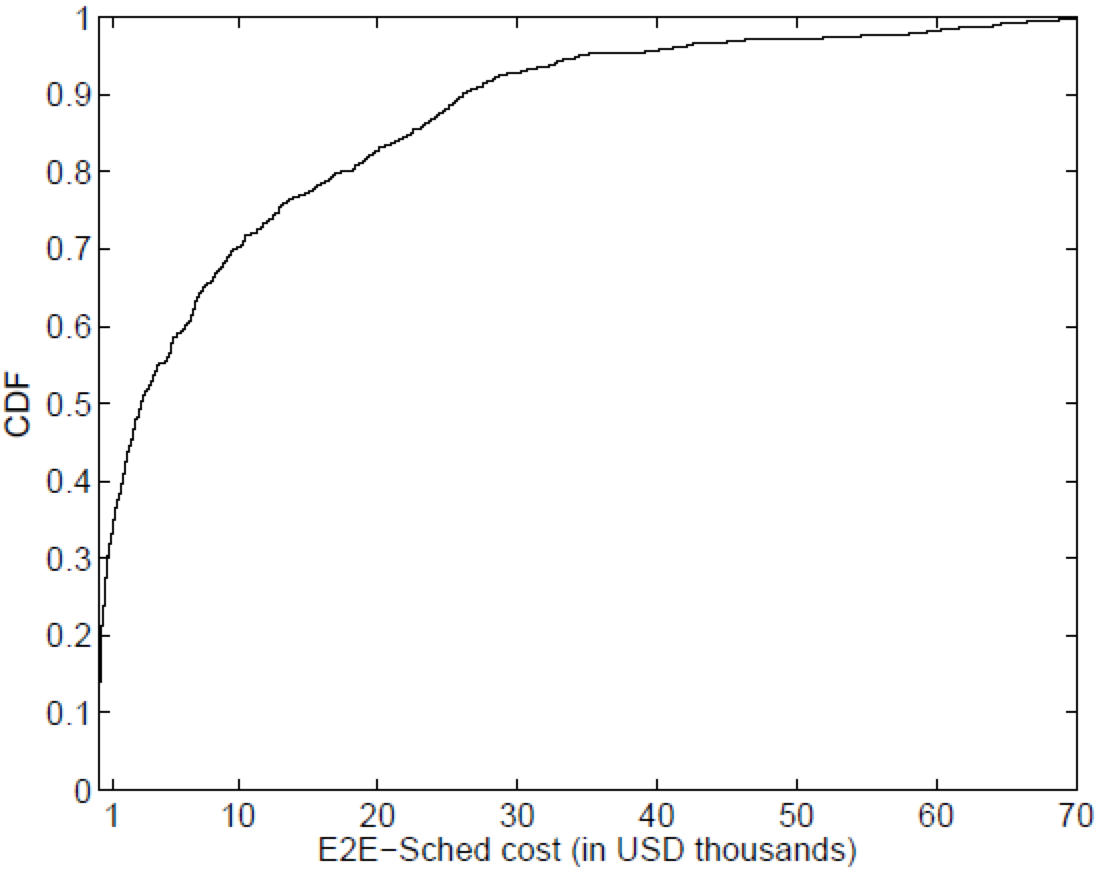
(c) Free volume ratio vs dissimilarity

Performance

- When the transfer volume B exceeds the volume which can be transferred for free, we need find *min-cost transfer*.
  - Definition: *Find charged volumes* $q_v \geq q(x_v)$ *and* $q_u \geq q(x_u)$ *to minimize the extra transit cost* $C(P,B) = c_v(q_v) - c_v(q(x_v)) + c_u(q_u) - c_u(q(x_u))$, *subject to constraint* $B(P, q_v, q_u) = B$.
- From the experiment, the SnF is suitable under this situation
- *"How much does it cost to send with E2E-Sched the same volume of data that SnF can send at zero transit cost?".*

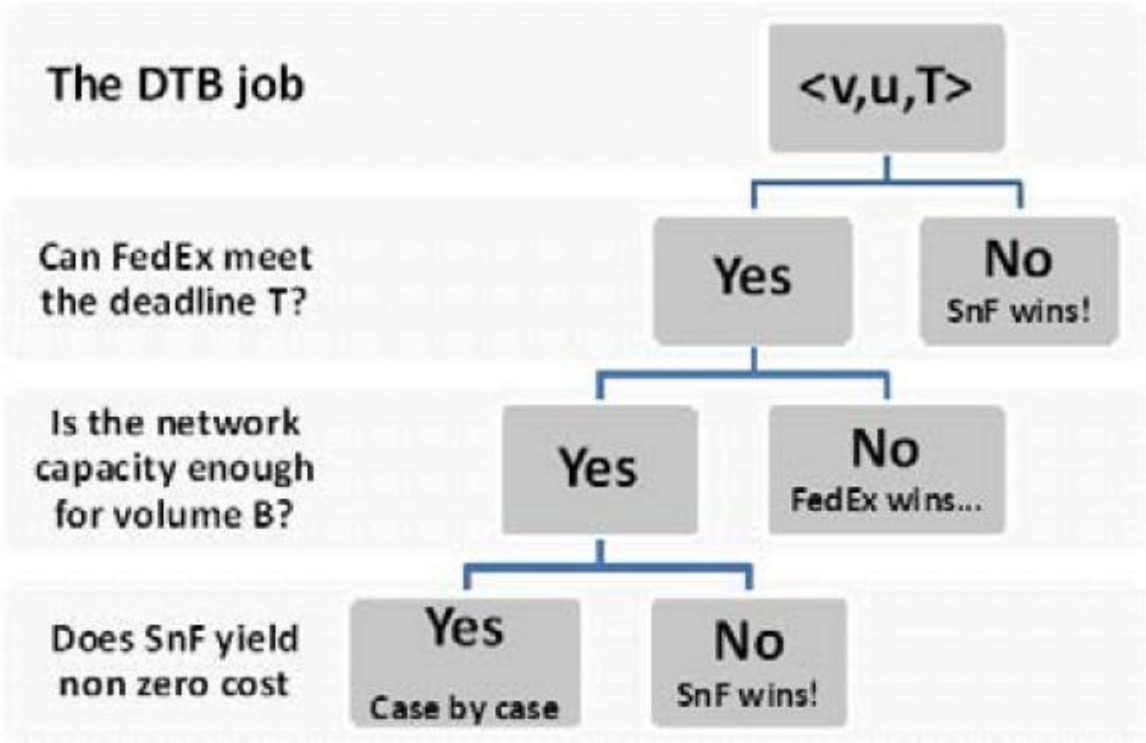
Performance

- From this we can see that *for 50 percent of the pairs in TR, E2E-Sched has to pay a transit cost of at least $5K to match the volume that SnF sends at zero transit cost.*
- An estimation of additional cost of transit storage node w was given in paper.



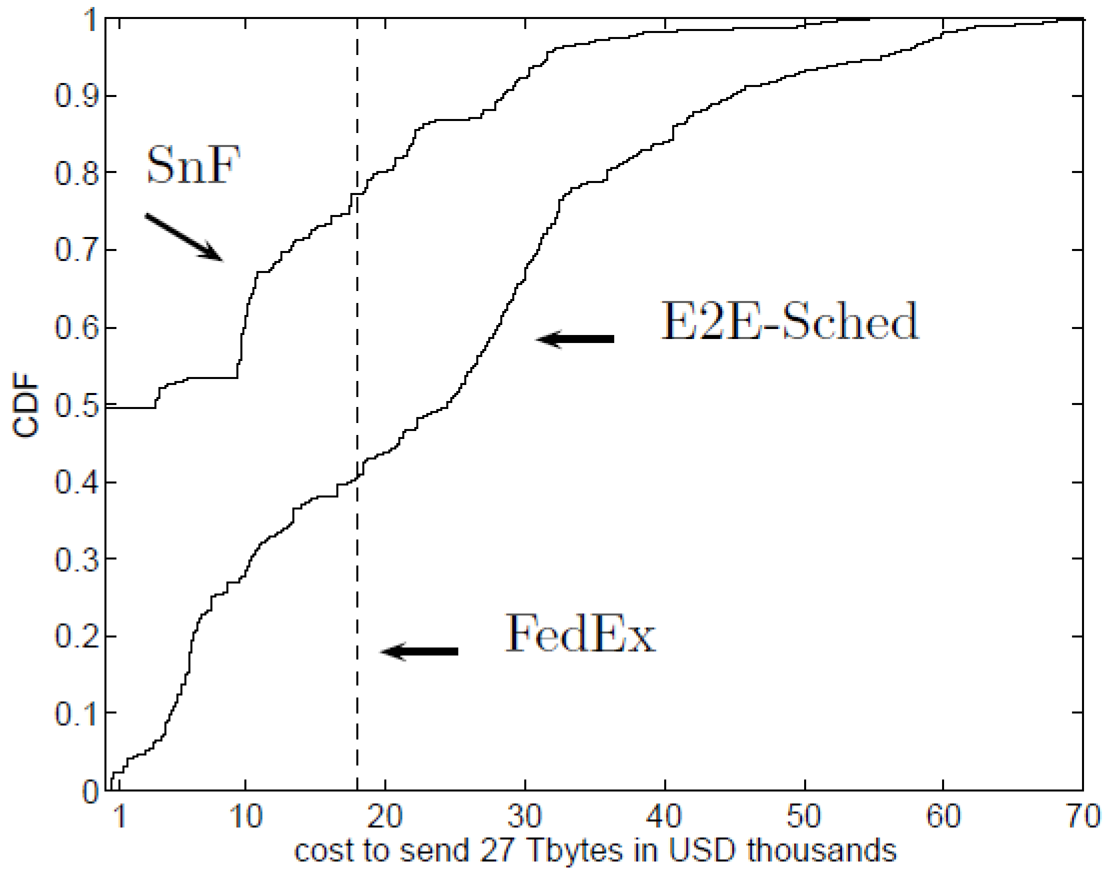
SnF VS. Courier Service

- High-level Comparison



SnF VS. Courier Service

- Example of sending 27Tbytes from EU to LAT
- From the figure, *38% of pairs achieve lower cost than FedEx using E2ESched, whereas the corresponding percentage using SnF is 70%.*
- In conclusion, a single shipment of courier service is cheaper, but it stops being cheaper when considering a continuous flow of data.



Related Work

- Network-layer approach: Scavenger service of Qbone
- P2P systems like Slurpie at application layer
- Percentile charging scheme
- Delay tolerant communication in wireless mobile network

Conclusions

- If E2E-Sched can send the DTB data for free then it is an obvious solution since it does not require transit storage.
- As the time-zone difference increases, and granted that the two end-points have comparable free capacity, thus allowing the time-zone difference to impact the end-to-end performance, SnF starts having a much higher advantage.
- Courier services are cheaper for individual shipments that occur infrequently, but when there is a constant flow of data to be transferred, then in many cases they are more expensive than SnF.

Future Work

- Several important implementation and architectural issues need to be studied and addressed.
  - Data encoding issue;
  - Error recovery issue;
  - Optimization of transport;
  - Multiplexing of multiple concurrent DTB jobs.
- Combining the existed business models with different pricing schemes to gain wealthy interests.

Discussion

- *“Whether transit ISPs will maintain 95-percentile pricing in view of DTB transfers?”*
  - Charging based on total aggregate volume
  - Additional cost
  - Changing the percentile
  - More complicated rules…

Questions

Questions???