Dexferizer: A service for data transfer optimization

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What does Dexferizer mean?

- Declarative
- Transfer
- Optimizer
Optimizing data transfers in personal data replication systems.

- **Personal data replication system:** phone, laptop, tablet, VMs, PCs,..
- **Challenge:** transfer data objects between devices while
  - satisfying user requirements for routing, privacy, etc.
  - optimizing for user objectives such as cost, bandwidth, power consumption.
Managing information on multiple personal devices is hard:

- **It’s on my other computer!**: Computing with multiple devices. D. Dearman et al., *CHI 2008*
- **Mobile kits and laptop trays**: managing multiple devices in mobile information work. A. Oulasvirta et al., *CHI 2007*

Systems on personal data management:

- **Cimbiosys**: A platform for content-based partial replication, V. Ramasubramanian et al., *NSDI 2009*
- **Perspective**: Semantic data management for the home, B. Salmon et al., *FAST 2009*
- **Eyo**: Device-Transparency: A new model for Mobile Storage. *HotStorage 2009*
- **UIA**: Persistent personal names for globally connected mobile devices. B. Ford et al., *OSDI 2006*
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Configuring and optimizing data transfers in such systems is important.
Money is a scarce resource

Data transfer on 3G connections can become complicated and costly!

<table>
<thead>
<tr>
<th></th>
<th>NATEL® BeFree</th>
<th>NATEL® Liberty largo</th>
<th>NATEL® Liberty medio</th>
<th>NATEL® Liberty primo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calls to all Swisscom networks</td>
<td>unlimited</td>
<td>0.30/hour</td>
<td>0.50/hour</td>
<td>0.70/hour</td>
</tr>
<tr>
<td>Calls to all networks of other providers</td>
<td>unlimited</td>
<td>0.50/hour</td>
<td>0.70/hour</td>
<td>0.90/hour</td>
</tr>
<tr>
<td>Data included per month</td>
<td>unlimited</td>
<td>1 GB</td>
<td>250 MB</td>
<td>100 MB</td>
</tr>
<tr>
<td>SMS incl. per month</td>
<td>unlimited</td>
<td>250</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Subscription price/month</td>
<td>$193</td>
<td>$85</td>
<td>$51</td>
<td>$33</td>
</tr>
</tbody>
</table>

- **$0.11/MB** once the bandwidth cap is used up.
- **Roaming**

<table>
<thead>
<tr>
<th>Region</th>
<th>EU/Western Europe</th>
<th>Eastern Europe/Top Countries</th>
<th>Rest of the world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data price/24h</td>
<td>$8 / 24h (or up to 5 MB)</td>
<td>$16 / 24h (or up to 5 MB)</td>
<td>$0.34 / 30KB (volume-based tariff)</td>
</tr>
</tbody>
</table>


Money is a scarce resource

- Liberty Medio plan and a user taking photos with a phone (~700KB each)
- Replication policy: “Replicate photos on at least 3 other devices”

- 2.1MB to replicate a single photo.

- 119 photos reach the bandwidth limit, further copies $0.24 each.

- 5 pictures a day (150/month) leads to $58.7/month just for photo replication.

- Let’s not even mention any roaming scenarios!
Time is a scarce resource

Scenario: Home server crash.
  - Find the ‘best way’ to re-replicate the items at risk.
Energy is a scarce resource

- Data transfer on 3G connection consumes a lot of power!
  - Handheld and mobile devices can save a lot of battery power if 3G or WiFi usage is minimized.

<table>
<thead>
<tr>
<th>Device State</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3G connection sending a file at 150 kbit/s</td>
<td>375 mA</td>
</tr>
<tr>
<td>3G connection receiving at 200 kbit/s</td>
<td>275 mA</td>
</tr>
<tr>
<td>Media player playing MP3, one step above mute</td>
<td>110 mA</td>
</tr>
<tr>
<td>Camera active, showing preview, back-light off</td>
<td>210 mA</td>
</tr>
<tr>
<td>Camera active, showing preview, vibration at max</td>
<td>310 mA</td>
</tr>
</tbody>
</table>

Personal data replication system developed at ETH Zurich.

- Declarative replication policies, PRACTI-like data store, Paxos for synch.
Personal data management via declarative replication policies.

**Dexferizer**: Part of the reasoning engine and decides on how best to carry out requested transfers.
Declarative information flow inside Dexferizer:

*ECLiPSe CLP as declarative language of choice
Representation

- System representation
  - Bosphorus - January 19, 2011
  - Nokia N900 smartphone

item(photos/bosphorus.jpeg, 'JPEG', 1295448700, public,...).
device(nokiaN900, mobile, phone, owned,...).

*ECLiPSe CLP as declarative language of choice*
Representation

- **System representation:**
  
  item(photos/bosphorus.jpeg, 'JPEG', 1295448700, public,...).
  
  device(nokiaN900, mobile, phone, owned,...).
  
  link('nokiaN900','desktop', '3g', 178.742752, 150, 375, ...).

- **Predicates** to reason on item, device, and network properties:
  
  picture_item(ItemID) :-
    item{itemid:ItemID, type:'JPEG'};
    item{itemid:ItemID, type:'PNG'}.

  phone_device(ResID) :- device{resid:ResID, type: phone}.

  any_device(ResID)    :- device{resid:ResID}.
Dexferizer workflow

- Transfer Policies
- Transfer Priorities
- Routing data
- Item Location data
- CLP Solver
- Transfer Schedules
Policies

- **Transfer policy grammar:** `xfer_policy(IP, SrcP, DstP, TR, LP)`.

- **Transfer policy example 1:**
  
  “Do not use a phone as a transfer source while replicating items.”

  `xfer_policy([any_item], [phone_device], [any_device], [xfernone], [any_link]).`

- **Transfer policy example 2:**

  “Never copy any of my video files over a 3G connection.”

  `xfer_policy([video_item], [any_device], [any_device], [xfernone], [3g_link]).`
Dexferizer workflow

- Transfer Policies
- Transfer Priorities
- Routing data
- Item Location data
- CLP Solver
- Transfer Schedules
Priorities

**Priority policy grammar:**

\[ \text{xfer\_priority([IPList, IPList, IPList, ..])}. \]

**Priority policy example:**

"Any document item tagged by the user as private should be treated with the highest priority in a transfer situation. Photo items are of the second highest priority, followed by the video items."

\[ \text{xfer\_priority([doc\_item, private\_item], [picture\_item], [video\_item]).} \]
Dexferizer workflow

- Transfer Policies
- Transfer Priorities
- Routing data
- Item Location data
- CLP Solver
- Transfer Schedules
Optimization

- Involves formulation of optimal transfer schedule search on to a built-in search routine in ECLiPSe CLP.

- Incorporation of *end-points* information:
  - Source, destination and difference matrices. (Details in the paper)

- Incorporation of *routing* information:
  - Necessary to cover multi-hop scenarios.
  - Customizable declarative routing algorithms that can optimize for cost, bandwidth, latency, power consumption.
Optimization

- Cost/Utility matrix: needed to compare potential solutions.
- Employ a 2D cost/utility matrix
  - Rows represent destination, columns represent source
  - Cells of the matrix say how good/bad that transfer operation is.

Flexible cost/utility specification:
- Bandwidth as *utility*
- Network latency as *cost*
- Money as *cost*
- Power consumption as *cost*

Optimizer maximizes the utility, or minimizes the cost
Evaluation

Experimental and simulation setup:

- 7 devices: (desktop PC, office PC, laptop, smartphone, home server and 2 rented cloud VMs)
- Various synthetic workloads

Goals of the evaluation were to investigate:

- Optimization
- Tunability
- Scalability & resource consumption
Evaluation: Optimization

- Multi-hop transfer simulation

Data set:
- 155 items
- 4-25MB
- 1-2 initial copies
- 1 new copy
Evaluation: Optimization

- Multi-hop transfer simulation

- Naïve approach always transfers from the first node it finds
- Dexferizer generates BitTorrent-like transfer schedules

Data set:
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Evaluation: Tunability

“Do not use a phone as a transfer source while replicating items.”

\[
\text{xfer\_policy([any\_item], [phone\_device], [any\_device], [xfer\_none], [any\_link])}.
\]

Data set:
3 initial copies
3 new copies
Evaluation: Tunability

“Do not use a phone as a transfer source while replicating items.”

\[ \text{xfer\_policy([any\_item], [phone\_device], [any\_device],[xfer\_none], [any\_link]).} \]

Data set:
- 3 initial copies
- 3 new copies

Activation of the policy dramatically reduces the replication originating from the phone
Evaluation: Tunability

- \texttt{xfer\_priority([[\texttt{picture\_item, private\_item}], [\texttt{video\_item}]]).}
Evaluation: Tunability

- `xfer_priority([[picture_item, private_item], [video_item]])`.

- The set of private photos (about half of the collection) gets scheduled earlier.
Evaluation: Scalability

Data set 1:
3 initial copies
3 new copies

Data set 2:
2 initial copies
2 new copies
Data set I:
- 3 initial copies
- 3 new copies

Data set 2:
- 2 initial copies
- 2 new copies

- Data set can significantly influence the solving time.
- Most of the time the system needs to deal with a few items at a time.
- Equivalence classes can be an option to further improve performance.
Future work

- Comprehensive evaluation (power, cost savings).
- More information into the framework:
  - Cloud pricing models
  - Usage profile integration
  - Time schedules
- GUI (end-users do not write Prolog!)
- User study of common policy libraries.
Conclusion

Summary

- We presented Dexferizer
  - a declarative framework that,
  - accommodates flexible user-specified transfer policies
  - optimizes the transfer of data objects.
- Potential to save money, time, power.

URL: [www.systems.ethz.ch/research/projects/anzere](http://www.systems.ethz.ch/research/projects/anzere)
Email: [eucan@inf.ethz.ch](mailto:eucan@inf.ethz.ch)