Dissemination–based Systems

- Applications
  - News services (RSS feeds)
  - Multiplayer network games
  - Real-time financial services
- Common facilities
  - Overlay network construction
  - Membership management
  - Data routing
  - Optimization

Application-aware Overlay Networks for Data Dissemination

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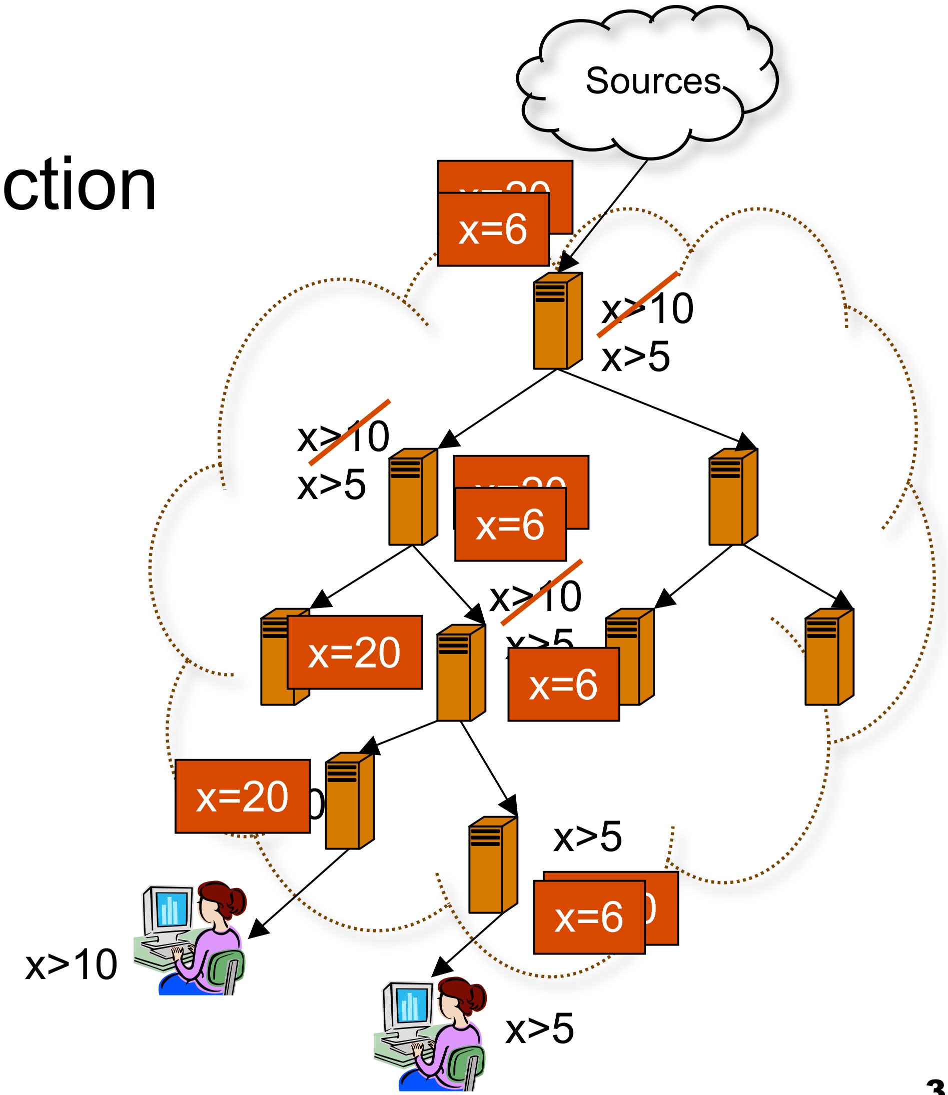
Publish Subscribe Model

- Overlay tree construction
- Clients register
- Profiles ***merging***
- Message ***matching***
    - Message routing to interested clients



Application-specific Profile/Data Types

- Dissemination systems provide solutions for:
  - Message-Profile matching
  - Profile merging
  - Profile storage and indexing
- Existing approaches:
  - XML stream dissemination
    - e.g. ONYX[ref]
  - Relational data matching, storing and dissemination
    - e.g. SIENA [ref], GRYPHON [ref]
  - XPath profiles matching & storing
    - e.g. XTrie []ref], YFilter [ref]

Application-specific Cost Metrics

- Latency-related metrics
  - matching time, forwarding cost, latency
- Bandwidth-efficiency metrics
  - bandwidth consumption
- Fairness metrics
  - bandwidth utilization across nodes
- Reliability metrics
  - message loss rates

XPORT

- Distributed dissemination-based system
  - Supports extensibility in:
    - Profile and data management
      - match, merge, indexing
    - Performance goals
      - system cost, constraints
  - Provides metric-independent optimization

Profile Extensibility in XPORT

- Applications provide methods for handling their profile and data types

match (*message*, *profile*)	Returns true if *profile* matches *message*
merge (*profile*, *profile*)	Creates a more general profile
initializeIndex() add (*profile*)	Initializes *index* Adds *profile* to the *index* structure
match (*index*, *profile*)	Returns *index* entries matching *profile*

Cost Extensibility in XPORT

- Uses a two-level aggregation model
  - Level 1: Defines the *local* node cost
    - Aggregation of a metric of some neighbors
  - Level 2: Defines the *global* system cost
    - Aggregate costs of all nodes
- Provides grammar for metric specification
- Uses same model for metric constraints

Performance Metric Examples

- Average path latency
  - system cost = average (path latency)
  - path latency = sum (link latencies on path)
- Bandwidth bottleneck
  - system cost = min (path bandwidth)
  - path bandwidth = min (link bandwidth)
- Variance of path latency
  - system cost = variance (outgoing bandwidth consumption)
  - path bandwidth = sum (incoming data of all children)

Application-aware Optimization

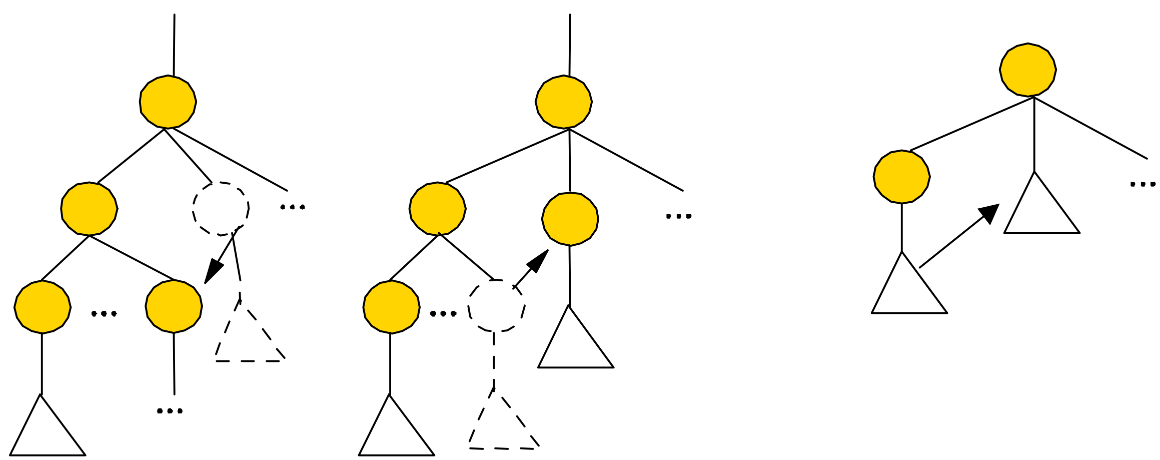
- Applications define their optimization goals
  - Define *node cost* and *system cost*
  - Define *constraint metrics* and their thresholds
- Applications define their optimization rules
  - Composite new network reorganization steps
- XPORT customizes optimization to the application's goals
  - Identifies beneficial network reorganizations with respect to these metrics

Optimization Protocol

- Divide network to sub-networks (*optimization units*)
  - One node responsible for each unit
  - Network units could overlap, but handled independently
- Consider transformations of each unit's structure
  - Identify minimum cost *local* transformation
  - They should guarantee *global* cost improvement
- XPORT applies best *local* transformation among all units
  - Transformation with higher benefit on *global* system cost
  - Multiple units can be optimized in parallel

Network Transformations

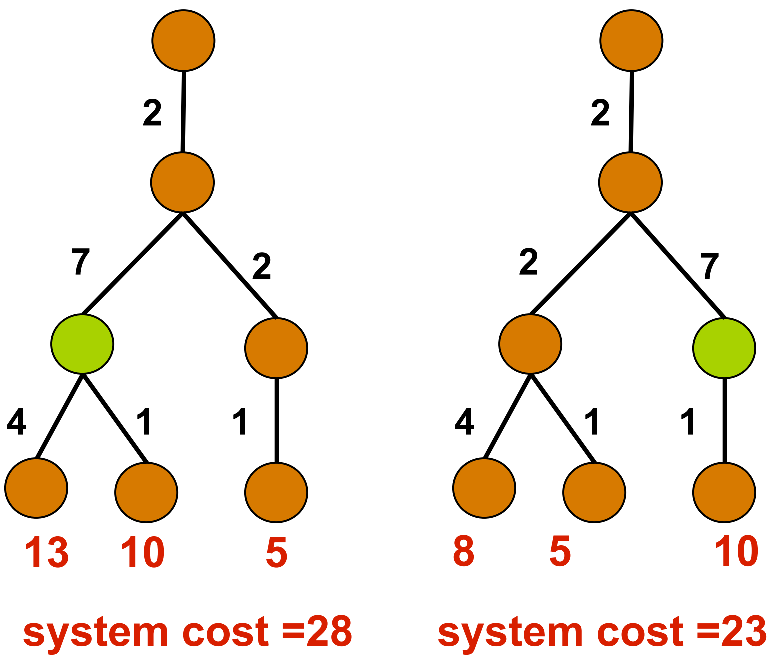
- XPORT provides two primitive transformations
  - child promotion & child demotion
- Applications define composite transformations
  - e.g. subtree promotion & subtree demotion



Quantifying Cost Improvements

- Exploit semantics of aggregation functions to quantify a transformation's cost benefit
- Use metric-independent cost model
  - Main idea: *identify nodes affected by a transformation and maintain aggregated state to quantify their cost changes*
  - Avoid any communication outside the optimization unit
- Based on function semantics automatically identify:
  - Stored state required
  - Metadata exchanged for optimization purposes
  - $O(1)$ for most aggregation functions

Example for sum of path latency



system cost =(2-7) x 2 + (7-2)x1 = 5

- Identify affected nodes
  - Link latency changes are reflected on the descendants' latency
- Node state required
  - Size of subtree
- Total cost change
  - *cost change* x *subtree size*
- No communication required with affected nodes

Optimization Approaches

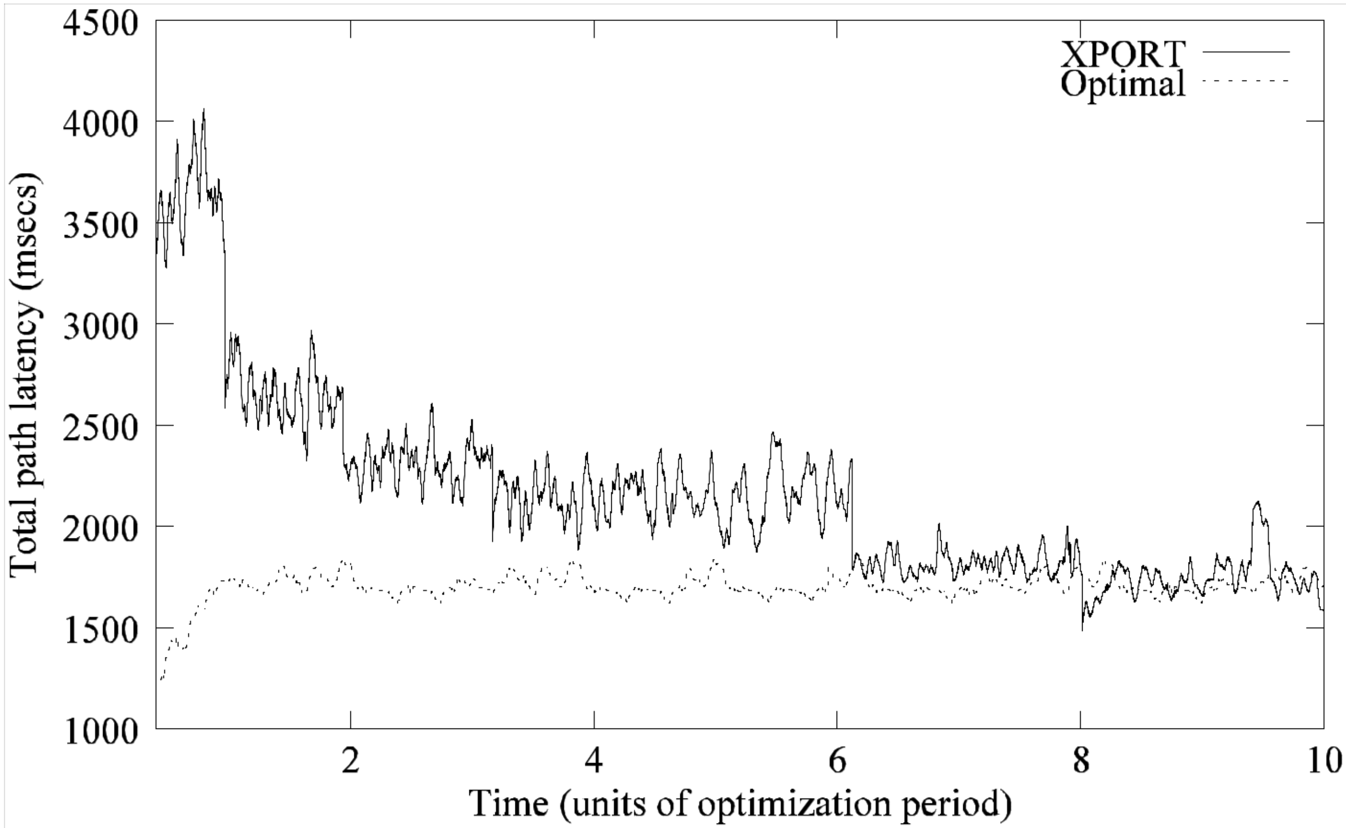
- Bottleneck-based
  - Optimize global cost
    - max CPU load in network
  - Optimize critical units
    - Units with max CPU load
  - Guarantees improvement
  - Reactive optimization
    - Work on units with most loaded node

- Opportunistic-based
  - Optimize cost of unit
    - max CPU load in unit
  - Optimize all units
    - Independent from CPU load
  - No improvement guarantees
  - Proactive optimization
    - Could prevent nodes from increasing their CPU load

RSS Feed dissemination

- XPORT distributes RSS feeds
- Clients connect to a proxy and send their requests
- Root periodically polls RSS sources
- Benefits:
  - RSS sources experience less load
  - RSS clients receive more timely updates

Deployment on Planet Lab



XPORT converges to the optimal topology after 8 transformations

Future Work

- Stateful subscriptions
- Message customization
- Collection & dissemination integration
- High-level profile languages
- Support overlay meshes

Stateful Subscriptions

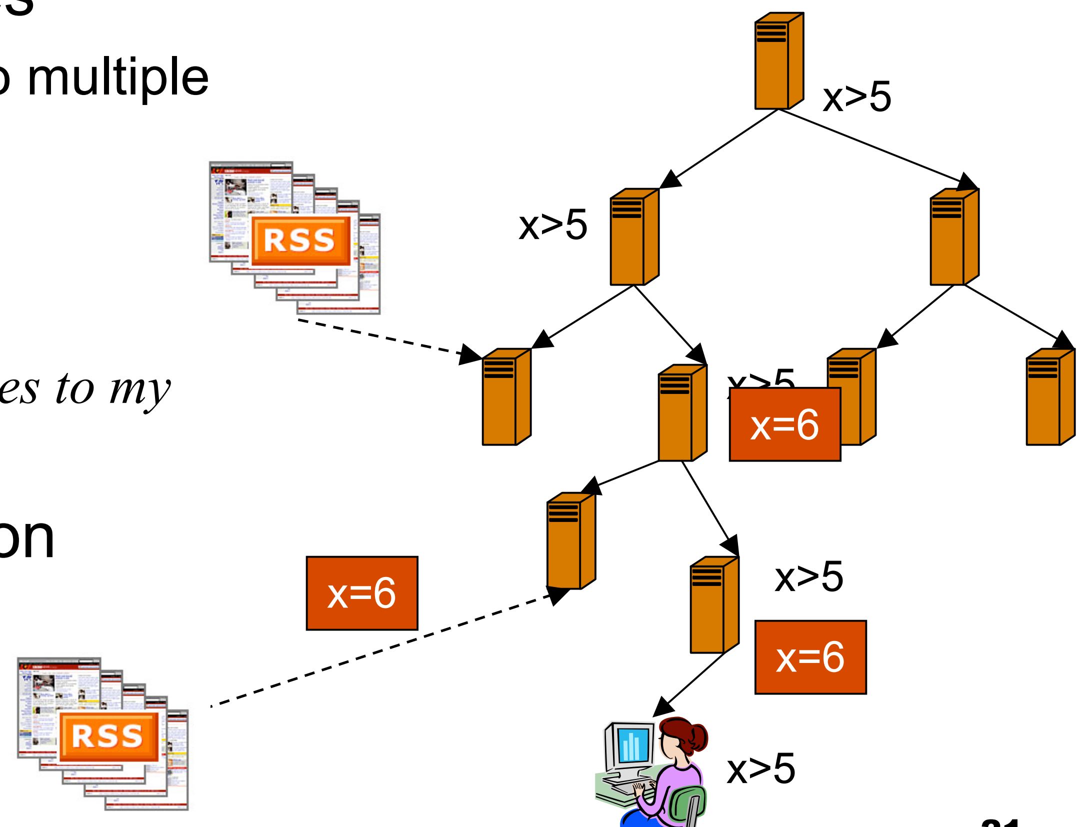
- "*Drop similar messages if they arrive within less than 10 secs*"
- *match* method should maintain state
  - e.g. *messages of last 10 secs*
  - Global state per application
    - Operations have similar semantics for each client
  - State per profile
    - Clients specify independent stateful operations

Incoming Message Customization

- Transform message structure and values
  - Map message values to different domains
  - e.g. XPath profiles
- *match* method will support data transformation
  - Returns the output message

Collection & Dissemination Integration

- Create a collection network to pull data from sources
  - Distribute overhead to multiple nodes
- Define new primitive transformations
  - *Assign part of my sources to my parent*
- Combined optimization
  - Short circuit



High-level Profile Languages

- Complex profile types are hard to specify
  - *Give me those news that do not look like the ones I received during the last two days*
- XPORT will provide native profile language
  - Built-in stream-oriented operators
  - Users can express complex profiles
  - XPORT automatically derives the API methods based on the operators' semantics

Support Overlay Meshes

- Create and optimize an overlay mesh
  - Improves throughput and reliability
- Extend optimization framework
  - 3-level aggregation
    - Global cost is the aggregation of each tree cost
  - Improve cost across multiple trees

Conclusions

- We explored extensibility in overlay routing trees
  - Profile-based data dissemination systems
- We designed and implemented XPORT
  - Application-aware dissemination-based infrastructure
  - Highly extensible and application customizable