Distributed Optimization of Event Dissemination Exploiting Interest Clustering

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DVS

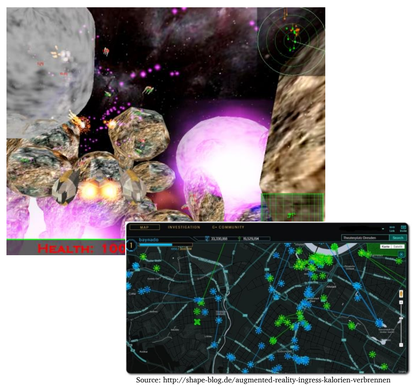
Goals

Interactive real-time online applications (e.g., games) need **timely many-to-many event dissemination**

Latency is critical → direct communication

↕ trade-off

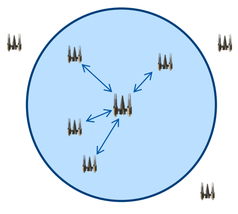
Bandwidth is limited → aggregation



Source: http://shape-blog.de/augmented-reality-ingress-kalorien-verbrennen

Further Challenges

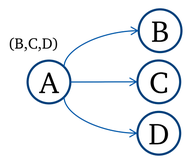
- High dynamism in interest sets
- Heterogeneity in interest and capabilities
- No guarantees wrt. delivery, latency
- Streams of small update events



Existing Concepts

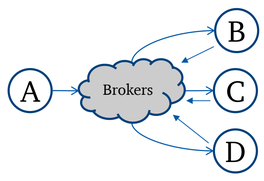
Application layer multicast

+ Efficient & scalable message dissemination
− No prioritization
− Group operations (join/leave) expensive



Publish/subscribe

+ Abstraction & decoupling, receiver-based selection
− Brokers are necessary infrastructure & bottleneck
− Subscription updates expensive



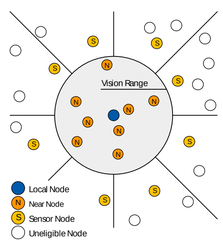
Context-aware [1] **/ parametric** [2] **pub/sub**

+ No need for full re-subscription
~ Systems needs to be aware of context changes

subscribe(type = Action
∧ myPos.x − 10 ≤ x ≤ myPos.x + 10
∧ myPos.y − 10 ≤ y ≤ myPos.y + 10)

P2P gaming overlays (VON [3], pSense [4])

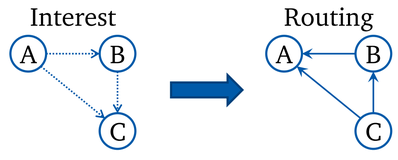
~ Interest management specific to virtual environments
+ Optimized for latency
− Event dissemination does not scale well

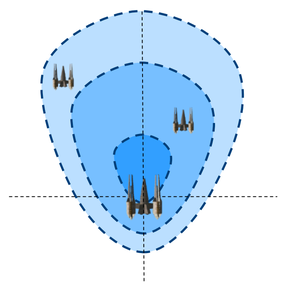


InterestCast

Interest-based Interface

Application-specific, continuous interest level is assigned to each neighbor





Interest Locality

Observation: interest in virtual worlds is local

Locality property: transitivity

$B \in I_A \wedge C \in I_B \Rightarrow C \in I_A$ with high likelihood I_X: interest set of node X

Metric: transitivity ratio or clustering coefficient (C)

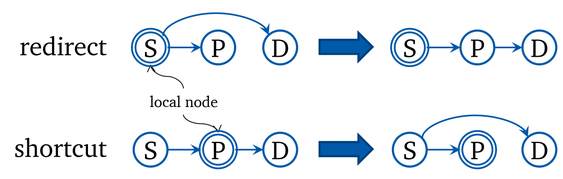
$$C = \frac{number\ of\ closed\ triplets}{number\ of\ connected\ triplets}$$

Interest locality introduces routing optimization potential:

- Shift load to more powerful nodes
- Aggregate messages, save connection overhead

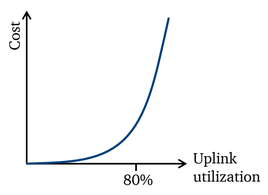
Local Optimization

- Each node locally evaluates utility
- Operations: redirect or shortcut

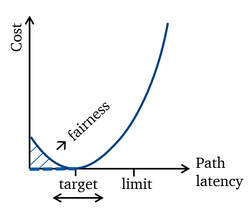


Utility Function

1. Link utilization



2. Path latency

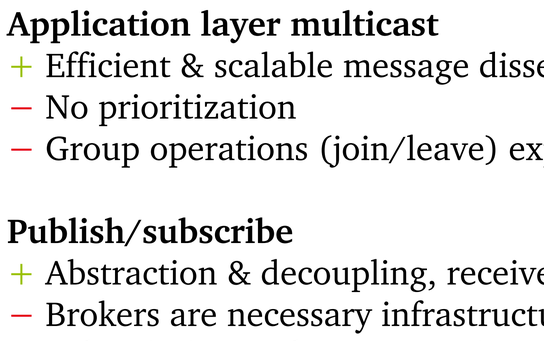


Finally: $utility = -c_{base}$ (transition cost)

bandwidth utility: $+ w_{bw\_S} * (c_{bw\_S\_before} - c_{bw\_S\_after}) + w_{bw\_P} * (c_{bw\_P\_before} - c_{bw\_P\_after})$

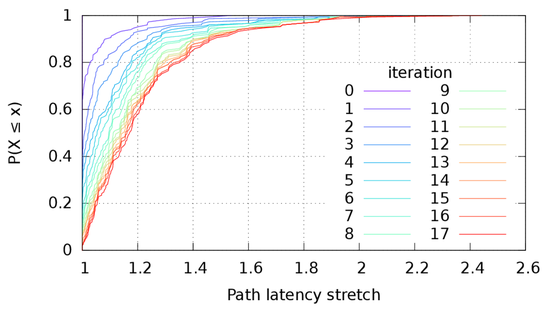
latency utility: $+ w_l * (c_{l\_before} - c_{l\_after})$

Evaluation



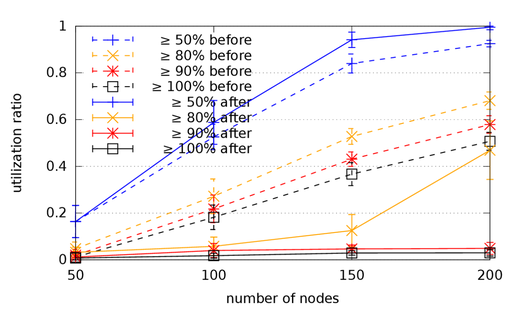
Virtual world interest graph

Link utilization distributions during a static optimization process



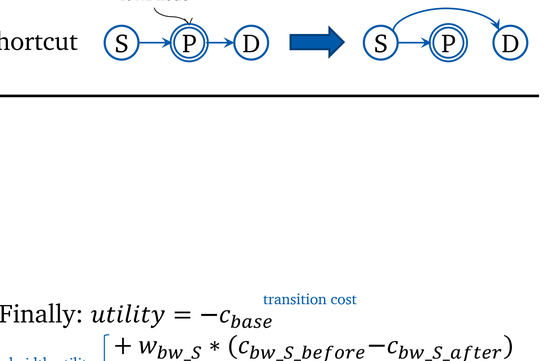
Path latency distributions during a static optimization process

Optimization potential depends on the node fan-out (proportional to number of nodes)



The effect of clustering on the optimization potential (synthetic interest graph)

Tuning utility weights to trade off link utilization against latency



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[1] Cugola G, Margara A, Migliavacca M.: *Context-Aware Publish-Subscribe: Model, Implementation, and Evaluation*. IEEE Symposium on Computers and Communications (ISSC'09). 2009:875–881.

[2] Jayaram KR, Eugster P, Jayalath C.: *Parametric Content-Based Publish/Subscribe.* ACM Transactions on Computer Systems. 2013;31(2):1–52.

[3] Hu S-Y, Chen J-F, Chen T-H.: *VON: A Scalable Peer-to-Peer Network for Virtual Environments*. IEEE Network. 2006;20(4):22–31.

[4] Schmieg A, Stieler M, Jeckel S, et al.: *pSense - Maintaining a Dynamic Localized Peer-to-Peer Structure for Position Based Multicast in Games*. Eighth International Conference on Peer-to-Peer Computing (P2P'08). 2008:247–256.

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Multi Mechanism Adaptation for the Future Internet

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