Hourglass: A Stream-Based Overlay Network for Sensor Applications

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Hourglass: Emergency Medical Care

Sensor support for emergency medical care
- Motes attached to patients collect vital signs (pulse ox, heart rate, . . .)
- EKG Mote with PDA runs on Windows CE platform
- PDAs carried by EMTs receive vital signs and enter field reports
- Ambulance correlates with patient records at hospital

Characteristics:
- Many heterogeneous patient sensors act as data sources
- Real-time streamed data
- Partial network connectivity to ambulance

Volcano Monitoring

Logging seismic activity of a volcano (Tungurahua) in Ecuador
- Sensors record low-frequency infrasonic (5 Hz)
- Survey physical structure of the inside of a volcano
- Many sensors → Mountain tomography

Application Features

Large number of distributed data sources
- Dynamic, heterogeneous sensors with imperfect network connectivity

In-network, real-time processing of data
- Aggregation close to sources
- Efficient resource utilisation

Multiple applications sharing sensor networks
- Different administrative domains with custom security policies

⇒ Need for a reusable and efficient Internet infrastructure for data collection and processing

Stream-based Overlay Network (SBON)

Main Components:
- Consumer (C)
- Producer (P)
- Service (S)
- Circuit

Pinned and unpinned services

Hourglass prototype

Placement Problem

Need to place unpinned services
- Placements have costs
- Optimisation problem
- Need approximation without global knowledge

Global and application costs
- Network utilisation
- Application delay penalty

Relaxation Placement

Model circuits as network of springs
- Spring extension
- Latency
- Spring constant
- Bandwidth

Minimises network traffic

Map solution back to physical space

Solve placement problem in virtual space
- Euclidean distance = latency
- 1550-node transit-stub topology
- Efficient encoding of global topology knowledge
- Scalable implementation

Evaluation

6 Placement algorithms in simulator:
- Optimal: exhaustive search
- Relaxation
- IP Multicast: place at M/C routers
- Producer/Consumer: place at P/C
- Random: random placement

Network Traffic

1000 4-producer circuits in simulator

Overhead traffic:

Optimal 1.00
Relaxation 1.15
IP Multicast 1.27
Producer 1.43
Consumer 1.60
Random 1.81

Future Work

Fully-decentralised implementation on PlanetLab
- Adaptable to network dynamics and circuit evolution
- Convergence results of distributed relaxation
- Explore potential of cross-circuit optimisation
- Investigate circuits used by realistic applications
- Large-scale circuit optimisation (reuse services)

Summary

SBONs enable future sensor applications
- Service placement is a crucial problem in SBONs
- Efficient resource utilisation and network awareness is important

Relaxation placement
- Spring relaxation model in latency space
- Scalable decentralised implementation with low comms. overhead
- Supports cross-circuit optimisation

Experiments
- Transit-stub topology: Relaxation is close to optimal; better than IP M/C
- PlanetLab: Verified results in shared networking environment

Node Load

Distribution of service placement
- Load-balancing?
- Transit domains more popular for service placement
- Traffic goes there anyway
- Enable transit domains for service placement
- Need a cap on maximum number of placed services

PlanetLab

Verified simulator results on PlanetLab
- Distributed test-bed with 339 nodes
- PlanetLab topology in latency space
- Physical topology of PlanetLab unknown
- Script route supports remote trace route

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