BlueDove Pub/sub
—A Scalable and Elastic Publish/Subscribe Service

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Emerging Smarter Planet Applications

“How is the traffic from my current location to my destination?”

Requires highly efficient messaging service
Challenges to Messaging Service

- Large number of clients, high information rate—*Scalability*

- Dynamic work load—*Elasticity*

- Personalized information—*Real time fine-grained filtering*

- Non-interrupt service—*High availability*
General Publish/Subscribe Messaging Model

- Store subscriptions
- Match events to subscriptions
- Push events to subscribers

- Decoupling of information producer/consumer
- Fine-grained event filtering
Existing Pub/Sub Systems

- **Centralized enterprise pub/sub**
  - Multiple fully connected, dedicated cluster servers

- **Peer-to-peer public pub/sub**
  - Large number of partially-connected, global-distributed machines
  - Meghdoot, Pastrystring, Hermes
Centralized Enterprise Pub/Sub

- **Support enterprise applications**
  - Relatively static clients
  - Predictable work load
  - Strict requirement on response time

- **Design**
  - Centralized and relatively static servers
  - Fully connected topology
  - Subscriptions are replicated to all servers

- **Challenges**
  - Hard to provision for highly dynamic work load
  - Heavy administration when system scale is large
Peer-to-Peer Public Pub/Sub

- **Support public applications**
  - Clients join or leave frequently
  - Highly dynamic work load
  - Flexible requirements on response time and false rate

- **Architecture**
  - Publishers and subscribers also act as pub/sub servers
  - Servers form a self-maintained logical overlay
  - Subscriptions/publications are mapped to the overlay
  - Routing are done in multi-hop manner

- **Challenges**
  - Bottlenecks due to skewed distribution
  - Performance issues due to dynamics and heterogeneity of servers
  - Large network delay
- Centralized enterprise pub/sub

BlueDove Pub/Sub Cloud

- Peer-to-peer public pub/sub
BlueDove Pub/Sub Cloud Architecture

Clients
- Publisher
- Subscriber

Pub/Sub Servers
- Event
- Sub

Data Center

- Performance-oriented Event Forwarding
- Multi-dimension Subscription Assignment
- Gossip-based Single-hop Overlay
Gossip-based Single-hop Overlay

- Each server maintains global view of the overlay
  - The contact information of each other server
  - Enables one-hop forwarding

- Overlay changes are propagated by gossip
  - Each server periodically exchanges info with a few random servers
  - Any state change is propagated to the whole network in log(N) rounds

- Advantages
  - Auto, low-overhead maintenance
  - Low network delay
Multi-dimensional Subscription Assignment

- Multiple dimensions are mapped to the overlay simultaneously
  - Each dimension is partitioned into sections
  - Each server maintains a section of each dimension
  - Partition information is propagated by gossip and known by all servers

- Each subscription is mapped in all K dimensions and stored by K servers simultaneously
  - Each server maintains a separate index for subscriptions assigned on each dimension

- Advantages
  - Redundancy of servers
  - Allows us to exploit the skewness in distribution of subscriptions
Performance Oriented Event Forwarding

- **Select the most efficient dimension to match events**
  - Servers exchange per dimension load information through gossip
  - Different load metrics: #subscriptions, average response time, cpu load, ...
  - Each event has K candidate servers, one for each dimension
  - Select the server with the best performance metric

- **Policy 1: minimum number of subscriptions**
  - Does not work well in heterogeneous environment

- **Policy 2: minimum average response time**
  - May not adapt fast enough when server load changes quickly

- **Policy 3: minimum predicted response time**
  - $\text{Match\_Time} \times (\text{QLen}_{\text{old}} + T \times (\text{Event\_Rate} - \text{Match\_Rate}))$
  - Adapts to heterogeneous environment and fast changing server load

- **Advantage**
  - Exploits the skewness of subscriptions
  - Load balancing
Implementation

BlueDove Pub/Sub Server

Dispatcher
- Load Collector
- Load Predictor
- Subscription Forward
- Event Forward
- Dimension Select
- Partitioner

Pub/Sub Server
- Load Monitor
- Matching Engine
- One-hop Overlay
- Bootstrap
- Gossiper (Cassandra)

Subscriptions
Server Map
Testbed and Experiment Setup

- **Testbed**
  - 25 RC2 machines
    - 20 pub/sub servers; 3 dispatchers; 2 to simulate clients

- **Simulators simulate publishers and subscribers**
  - Each subscription or publication has four attributes
  - Each attribute in subscriptions represents a range of 200
    - The center of the range follow a Normal distribution cropped of range size 1000, standard deviation of 250, mean at 125, 375, 625, 875 for dimension 1-4
  - Each attribute in events represents a point in [0,1000]
    - The point follows a uniform random distribution

- **Metrics**
  - Response time: the time period from when a publication is generated to when it is received by corresponding subscribers
  - Saturation event rate: the highest event rate that the system can handle without publication queue overflow
Response time behavior to event rate

- **Response time series before saturation**: 40K subscriptions, 20 servers, 100K event/sec

![Graph showing response time series before saturation](image)

- **Response time series after saturation**: 40K subscriptions, 20 servers, 150K event/sec

![Graph showing response time series after saturation](image)
Impact of event rate to average response time

- Compare BlueDove to Full-replication scheme
  - 20 servers
  - 40,000 subscriptions
Scalability to event rate

- Fix number of subscriptions (40K), increase number of servers

![Graph showing scalability to event rate with different line types for bluedove, full-rep, and p2p.](image)
Scalability to number of subscriptions

- Fix event rate; increase number of servers
CPU load distribution

- **CPU load across different servers**
  - 20 servers; 40,000 subscriptions; 100,000 events per second for BlueDove,
    27,000 events per second for p2p scheme
Matching load distribution

- **Number of events** \((10^9)\) matched on different servers
  - 20 servers; 40,000 subscriptions; 100,000 events per second for BlueDove, 27,000 events per second for p2p scheme
Different Event Dispatching Policies

- Compare random, subscription-number-based, response-time-based and prediction-based policies

![Chart comparing event dispatching policies](image)
Elasticity upon increasing load

- Event rate increases continuously. Initially there are 5 nodes
Impact of the number of partition dimensions

- Fix the number of subscriptions and change the number of partition dimensions
  - 20 servers; 40,000 subscriptions
Impact of the skewness of the distribution of subscriptions

- Change the standard deviation of subscription distribution
  - 20 servers; 40,000 subscriptions
Summary

- A cloud based publish/subscribe service provides an answer to the challenge of interconnecting numerous information producers and consumers in the Smarter Planet.
- BlueDove exploits the skewness in data distribution and difference across multiple dimensions to achieve high performance.
- Evaluation has shown its linear capacity scaling and agile adaptation to changes in workload.
Thank you!

Questions?
Impact of the skewness of the distribution of events

- Change the number of event dimensions that are skewed in the same way as their corresponding subscription dimensions
  - 20 servers; 40,000 subscriptions
Future Work

- **Explicit load balancing**
  - Move subscriptions from overloaded nodes to less-loaded ones

- **Integration with BlueDove queue**
  - BlueDove queue takes the responsibility of pushing publications to subscribers

- **Persistence**
  - “outsource” data storage to a cloud-based storage (e.g. Cassandra)
Cross-data-center replication of subscriptions

- **Implicit replication**
  - Each subscription is already replicated to multiple servers
  - With high probability at least two servers are in different data centers

- **Explicit replication**
  - If all replicas are in the same data center, then explicitly make a copy in another data center