



Bandwidth Brokers

March 27, 2001
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Agenda



- Introduction
- Motivations
- High-Level Requirements
- Sample Implementation
- Future Work
- Summary

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Introduction



- Best Effort delivery of Internet traffic
- Future of Internet includes high-quality streaming audio and video
- Past: dedicated connection for high-quality
- Future: use of Internet and various quality of services
- Benefits: drastically lower cost and higher network utilization

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What is a Bandwidth Broker?



- A Bandwidth Broker (BB) manages a network domain and strives to ensure QoS by tracking system load and either accepting or rejecting the requests for bandwidth
- According to Webster, a broker is “one that acts as an agent for others, as in negotiating contracts, purchases, or sales in return for a fee or commission.”

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Motivations



- Additional revenue opportunities for ISPs
- Users who need high-quality connections will have less expensive alternatives with various preferred services
- Increased utilization of current resources for time-sensitive applications and non real-time applications

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Need for Bandwidth Brokers



- Necessary to provide reliable quality of service within and across networks
- A BB manages resources for a single domain
- Preferred services are allocated with policies and service agreements
- The BB configures network routers with correct packet forwarding behaviors
- The BB performs internal and external admission control

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High-Level Requirements

- Policy and Decision Making Requirements
 - Enforce the terms of the Service Level Agreements (SLAs).
 - Track/manage bandwidth resources within its domain.
 - Must not degrade performance or revoke resources to users already utilizing the domain.
 - Negotiate with BBs in adjacent domains to establish bilateral SLAs when sender and receiver are not within the same domain.

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High-Level Requirements (cont'd)

- Operational and Design Requirements
 - Authenticate the client that is requesting service (user, application, or adjacent BB).
 - Store the SLA specifications for clients to automate the granting or denial of access.
 - Configure routers and switches to appropriately forward packets.
 - Store data on the domain topology to facilitate “on-the-fly” configuration of domain elements.

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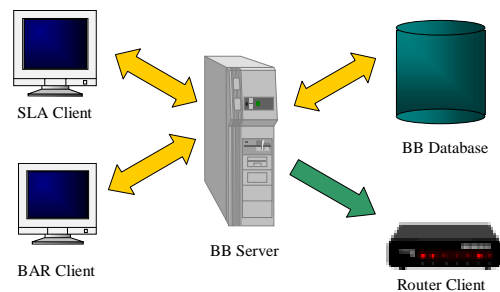
High-Level Requirements (cont'd)

- Operational and Design Requirements (cont'd)
 - “Leverage [the] DiffServ model...” Qbone Architecture
 - Be scalable
 - Utilize bilateral arrangements with adjacent BBs.
 - Design for future developments and functional add-ons.

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Bandwidth Broker Architecture



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*diagram adapted from <http://www.itc.ukans.edu/~kdrao/845/architect.html>¹⁰

Bandwidth Broker Database

- Purpose: The BB Database is the central repository that is used to track users, resources, and domain topology.
- What it stores...
 - SLA Data: The parameters of each user's service level agreement (i.e. limits on the amount of data that can be sent, the type of data that can be sent by that user, etc.).

* This data is stored for each SLA.

* A user can be an individual or an adjacent domain.

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Bandwidth Broker Database (cont'd)

- Resource Allocation Data: The database maps all resource allocations to the user's SLA. Data on the resource allocations for the current connections includes
 - user's ID
 - maximum amount of data
 - type of data to be transmitted/received while the connection is active

* This data is stored for each connection.

- Domain Topology Data: Topology data for the local domain, such as router and switch data, and data on the BBs in the adjacent domains.

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Bandwidth Broker Database (cont'd)

- How it works...
 - Accessed by the BB Server only.
 - It is updated with new SLA data whenever new SLAs are negotiated or terminated.
 - It is updated with new Resource Allocation data whenever a user is granted service or when the user cancels service.
 - It is updated whenever the domain topology is modified.

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Bandwidth Broker Server

- Purpose: The BB Server handles all communication between the BB components, performs authentication, and device configuration.
- What it is responsible for...
 - Granting/denying resources to requesting users both within and outside its domain.
 - Tracking the available and allocated bandwidth resources within its domain.
 - Negotiating with adjacent BBs to establish end-to-end communication.

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Bandwidth Broker Server (cont'd)

- How it works...
 - Continually listens for new client requests.
 - Authenticates users requesting service.
 - Grants/denies resources to the user.
 - Manages the resource usage for the new client.
 - Updates the BB Database.
 - Transmits configuration data to domain devices (routers, switches).
 - Negotiates with adjacent BBs to establish bilateral peer-based SLAs.

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Bandwidth Broker Command Line Interfaces

- Purpose: The BB Command Line Interfaces provide the functionality to request and modify user service.
- The types of Command Line Interfaces...
 - Service Level Agreement: Provides an interface for establishing an SLA either between user and service provider or between adjacent BBs.
 - Bandwidth Allocation Request: Provides an interface for clients to request resources.

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Bandwidth Broker Command Line Interfaces (cont'd)

- How it works...
 - Service Level Agreement
 - The user/service provider or BB/adjacent BB agree to terms for the SLA.
 - An SLA is sent to the BB Server containing the following information:
 - Customer Identification, Service Type, Service Type Parameters (rate, maximum burst, etc.), Service Restrictions.
 - The BB server adds the new SLA to the BB Database.

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Bandwidth Broker Command Line Interfaces (cont'd)

- How it works...(cont'd)
 - Bandwidth Allocation Request (BAR)
 - The user/adjacent BB sends a BAR containing the following parameters:
 - User Id, SLA ID, Service Level Parameters (rate, maximum burst, etc.), Source Identifier and Destination (port number, IP address, protocol), Duration of request.
 - The BB Server determines if the request meets the specifications of the user's SLA and if there are sufficient resources to grant the request.
 - The BB Server grants or denies the request.

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Bandwidth Broker Router Configuration Client



- Purpose: The BB Router Configuration Client configures the leaf routers in the domain to process data from a particular user.
- What it is responsible for...
 - Configuring the network elements to provide the desired level of service within the BB's region.
 - The configuration takes into consideration the SLA for that user and the incoming requests.

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Bandwidth Broker Router Configuration Client



- How it works...
 - A new connection is established and resources are allocated.
 - The BB Server determines which routers to send the data through to meet the QoS level specified by the user's SLA.
 - The BB Server configures the network elements so that the new traffic is routed appropriately.
 - The affected routers are refreshed so that the new configurations take effect.

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Resource Management



- Typical BB systems are designed to manage both internal and external resources
- Internal resource management is performed among the edge and core routers
- External resource management occurs between neighboring BBs

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External Resource Management



- Performed among the BB of neighboring networks
- Achieved through *signaling*
- Purpose of signaling
 - Notifies the receiving network of a traffic request
 - Negotiates SLA based on requested QoS and available resources in receiving domain
 - Contains information about data flow
- Link resources managed by BB of sender's domain

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Internal Resource Management



- Required to assure QoS within network and enforce bandwidth limitations defined by the SLA
- BB instructs the ingress routers on traffic policing to ensure that the requested QoS is met
- BB monitors core routers to ensure new data streams do not compromise previously reserved resources
- Achieved using several network components
 - BB server, BB database, routers, SLA, and BAR

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Bandwidth Broker Server



- Performs several tasks to ensure resource management throughout the network
- Interfaces with BB database, domain routers, and SLA/BAR clients
- Flow acceptance criteria: $C_{\text{request}} \leq C_{\text{total}} - C_{\text{allocation}}^*$
- Available bandwidth reduction:

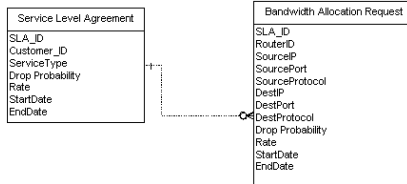
$$C_{\text{available}} = C_{\text{Total}} - (C_{\text{allocated}} + C_{\text{request}})$$

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* Khalil and Braun

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Bandwidth Broker Database

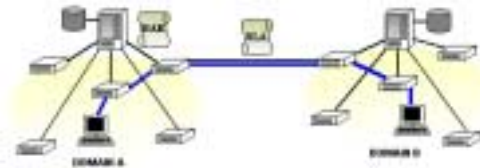


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* Sreekantan and Rao

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Sample Implementation of Bandwidth Broker

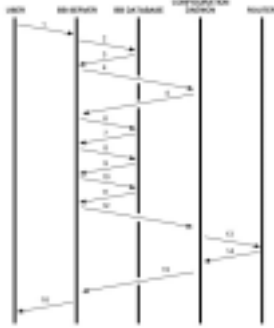


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Sample Implementation of Bandwidth Broker

- (1) Initiating BB transmits a BAR to adjacent BB
- (2) BAR sent to database for user validation
- (3) ACK received by server indicating resources are available
- (4) Server checks Config. Daemon (CD) for its availability



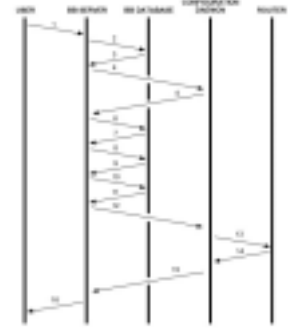
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* Khalil and Braun

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Sample Implementation of Bandwidth Broker

- (5) Message sent to server acknowledging CD
- (6) Database is queried to determine if connection already exists
- (7) Results of inquiry sent to server



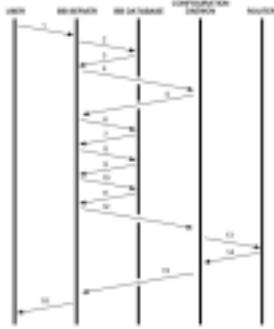
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* Khalil and Braun

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Sample Implementation of Bandwidth Broker

- (8) Inquiry to database to determine if any edge-routers can support BAR.
- (9) ACK sent to server and router available resources reduced
- (10) Server inquires about availability of core router resources



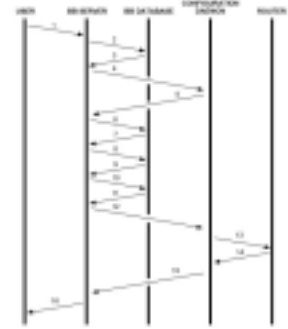
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* Khalil and Braun

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Sample Implementation of Bandwidth Broker

- (11) ACK sent to server and core available resources reduced
- (12, 13) Server sends script files through CD to appropriate routers
- (14, 15) Control returned to server through CD
- (16) ACK sent to user for transmission



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* Khalil and Braun

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Future Work



- **BB as a product distributor**
 - Same high-level requirements as a physical material lender.
 - Current focus is on refining resource allocation techniques.
 - Security issues (impenetrability) must be resolved.
 - Usage documentation (for billing) must be resolved.
- **Security issues outstanding**
 - Real authentication of bandwidth requests
 - Defeats SLAs if authentication compromised.
 - Possible mischarging.

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Future Work (security)



- Security issues outstanding [continued...]
 - **Network intrusion detection**
 - Topology may be modified without BB oversight
 - Physical security connecting elements cannot be guaranteed; network monitoring necessary.
 - **BB hardening against Denial of Service threat**
 - Strategic and full-force attacks on the Domain;
 - Sustained (in)valid requests must not overload the BB, blocking legitimate connections.
 - Can not assume BB has a trusted link to all routers and switches.

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Future Work (research)



- **BB research can be platform-independent.**
 - Selected current projects listed on right.
- **Admission Control research into...**
 - Handling of BARs.
 - Storing, accessing, and updating SLAs.
 - Per-use billing.

- **Cisco Topology**
 - Globus Architecture for Reservation Allocation
 - Reserved Bandwidth Service [MCI WorldCom]
- **FreeBSD Topology**
 - Diameter Bandwidth Broker [Merit Network]
 - Siemen's QoS
 - Telia Bandwidth Broker
 - UCLA BB Project
- **Linux Topology**
 - University of Kansas BB

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Internet2



- **QBone**
 - “an interdomain testbed for DiffServ that seeks to provide the higher-education community with end-to-end services...”
 - Overseen by Internet2 QoS Working Group
- **QBBAC**
 - QBone Bandwidth Broker Advisory Council
 - Drafting BB requirements
 - Coordinating existing BB research projects
- **IETF Differentiated Services Group**
 - Has defined excellent inter-router and policy communication bases.

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Summary



- Necessary for reliable QoS.
- Responsibilities include the management of internal and external resources.
- Several designs are being tested, however, no standards have been established.
- Considerable work remains in the fields of security and per-use billing.

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Review Questions



- What are the five main components of a Bandwidth Broker? Explain each.
- Explain the benefits of implementing Bandwidth Brokers?
- What is QBone?
- What is the relationship between an SLA and a BAR?
- What aspects of the BB model require continued research for successful implementation? Explain one.

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