Cross Stratum Optimization Research Proposal

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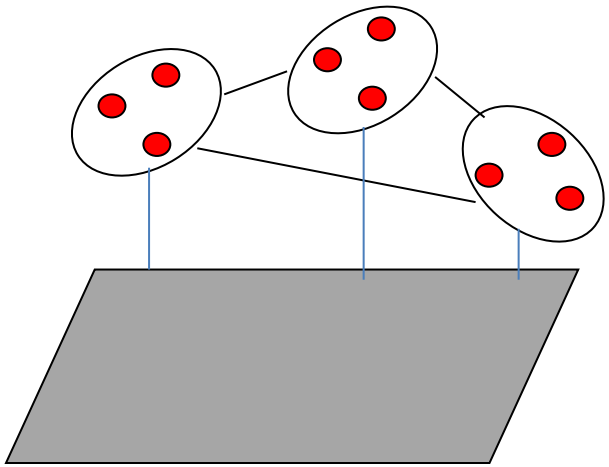
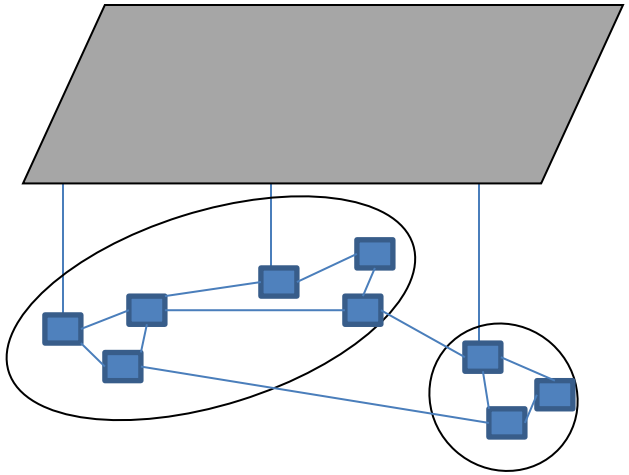
Current Approaches

Application Centric Approach



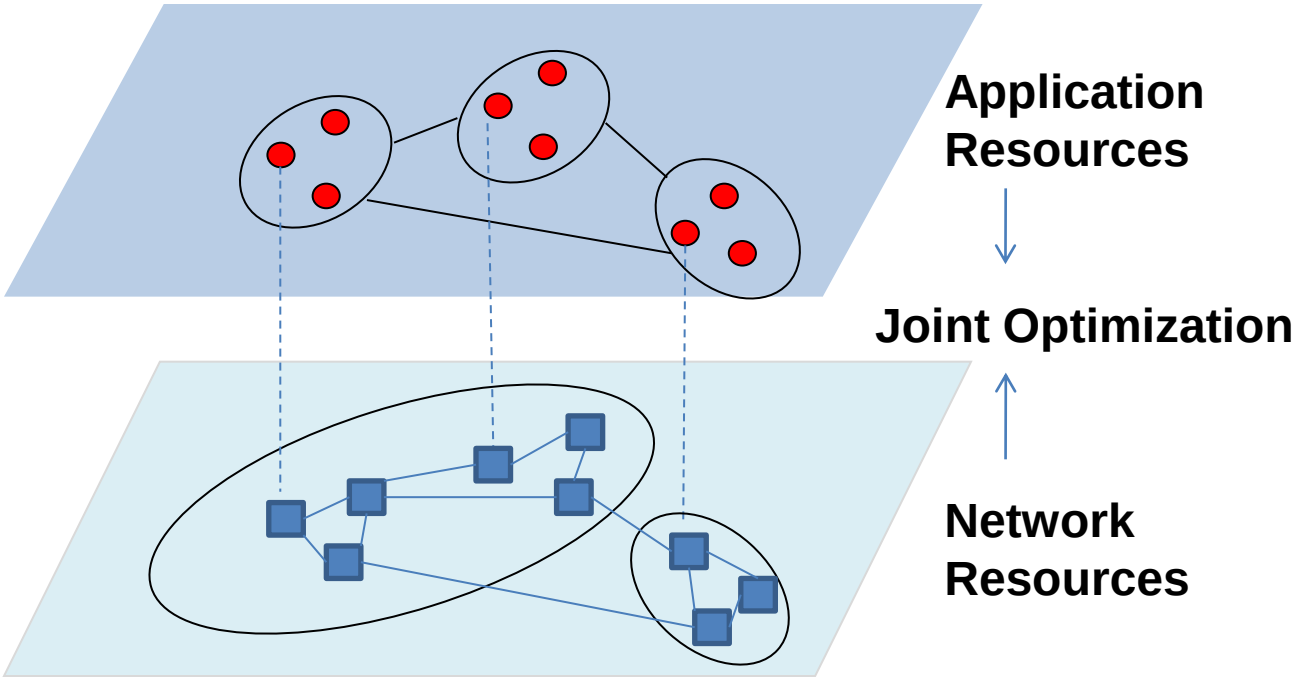
Application resources are allocated without knowledge of transport network condition and/or capability

Network Centric Approach



Network is not aware of application requirement and/or application resource conditions

CSO Approach



CSO is an approach that considers both application and network resources to achieve improved resource efficiency, user experience, and service resiliency.

CSO Goals

- Cross-stratum optimization is defined as cooperation between the application and network strata that aims to provide:
  - joint application/network resource optimization,
  - quality of application experience enhancement (via better use of existing network and application resources),
  - responsiveness to quickly changing demands from/to application to/from network, and
  - enhanced service resilience (via cooperative recovery techniques between application and network).

Key Research Problems

- How to choose the “best” location among distributed application resources (e.g. servers and storages in data centers) and the allocation of network resources (e.g. bandwidth, latency, jitter, and QoS)
  - This is a multi-source and multi-destination problem
    - Multiple application users/destinations (e.g. video gaming)
    - Multiple application hosts/sources (e.g. multiple data centers can host the application)
    - Key use cases: (i) server assignment problem; (ii) large data replication/backup
    - The dynamic nature of application resources (VM mobility) and network resources (user mobility) makes the problem even more challenging
- Research on algorithm efficiency
  - Multi-criteria and multi-constraint optimization
    - Network Constraints: B/W, Latency, Loss, Availability, etc.
    - Application Constraints: Server CPU, Memory, Intra DC/Cloud networking status, etc.
    - Quality of User Experience

Key Research Problems

- Scalability
  - Resource Information Abstraction
  - Information Dissemination
- Stability and Reliability
  - As application resources and network resources are shifted dynamically, how to assure stability and avoid oscillation?
  - Joint Application/Network recovery methods

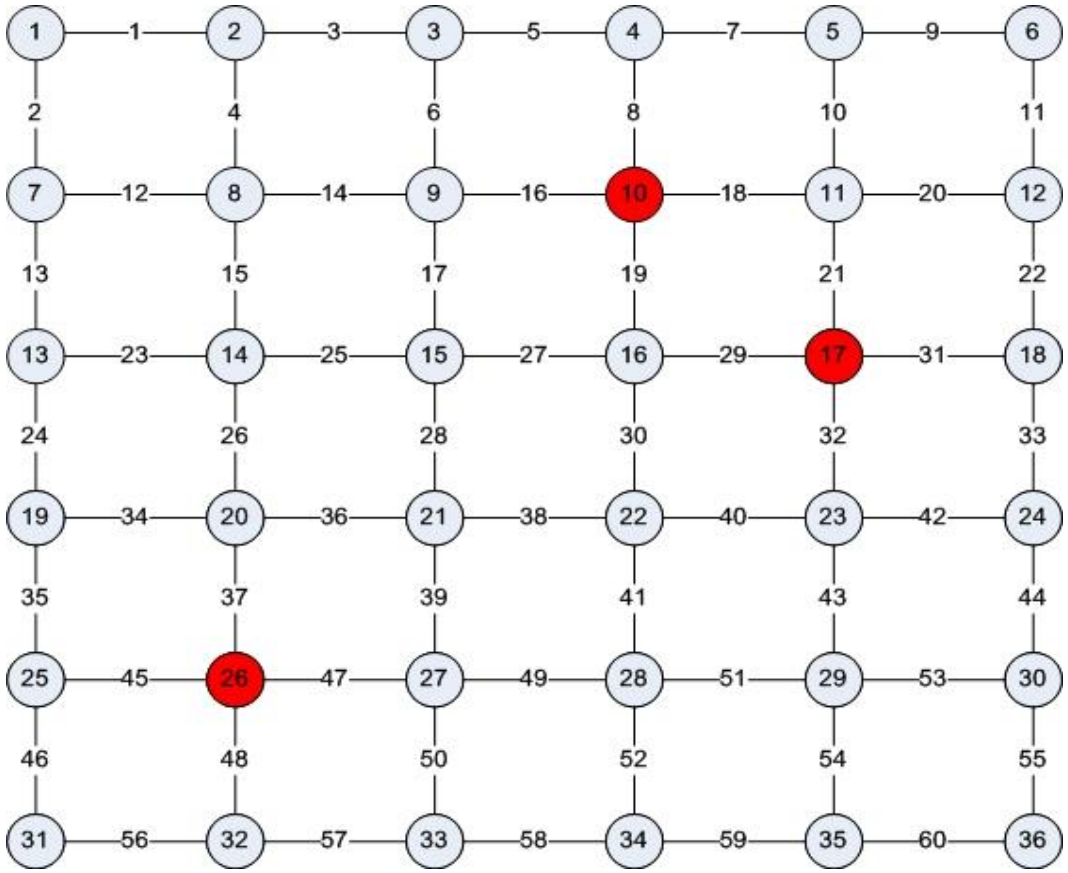
CSO Research Progress

- Pre-IRTF Side meetings held
  - Prague IETF, Beijing IETF and Quebec City IETF
- CSO Pre-RG page opened in 2011.
- 2011 Cloud Computing and CSO workshop held in Daejeon, Korea, June 2011.
  - A total of 12 contributions from academia, vendors, carriers and research institutes.
- Pre-IRTF Side meeting in 82nd IETF/IRTF meeting in Taipei
  - Preliminary research results show the proof of concept.
- 2012 International workshop on “CSO for cloud computing and distributed networked applications” in conjunction with 10th IEEE International Symposium on Parallel and Distributed Processing with Applications” (ISPA-12) in progress, Madrid, Spain, July 2012.

UTDallas Research Results

- A simplified use case: DC selection problem
  - Multiple users using a application that is offered by multiple data centers
  - Initial problem formulation based on ILP formulation
- Today's Solution:
  - Network Stratum driven: choose the closest DC based on shortest path or hop count irrespective of the load of the DC (solution A)
  - Application Stratum driven: choose DC in order to optimize (load balance) load at DC, then run shortest path in the network to reach the DC (solution B)
- CSO-based Solution: selection optimized for both stratum

UTDallas Research Results



- DC: red nodes
- Users: grey nodes

UTDallas Research Results

- Fixed Traffic

	QoE	QoE_BW	QoE_CPU	BWUsage
NET	0.567374	0.567374	0.894203	0.227653
APP	0.487873	0.487873	1	0.335471
CSO	0.995088	0.996078	0.99901	0.424703

- Random Traffic

	QoE	QoE_BW	QoE_CPU	BWUsage
NET	0.52293	0.52293	0.866666	0.220614
APP	0.474624	0.474624	0.985605	0.332219
CSO	0.985618	1	0.985618	0.431867

BUPT Research Results

- **Four strategies including GLB strategy based on CSO, RB, AB and NB strategies.**

Strategy Name	Application Resource Awareness	Network Resource Awareness	Comments
RB	No	No	The destination node of data center server is randomly selected by control plane when the application request comes.
AB	Yes	No	According to the memory, CPU and disk utilization, control plane chooses the server node having the minimum application utilization as the destination.
NB	No	Yes	Select the node which has the path of the minimum hop from the source to the destination.
GLB	Yes	Yes	AC selects the server node and the DC location based on the application status collected from data center networks and the network condition provided by SCs.

GLB Strategies and Algorithms

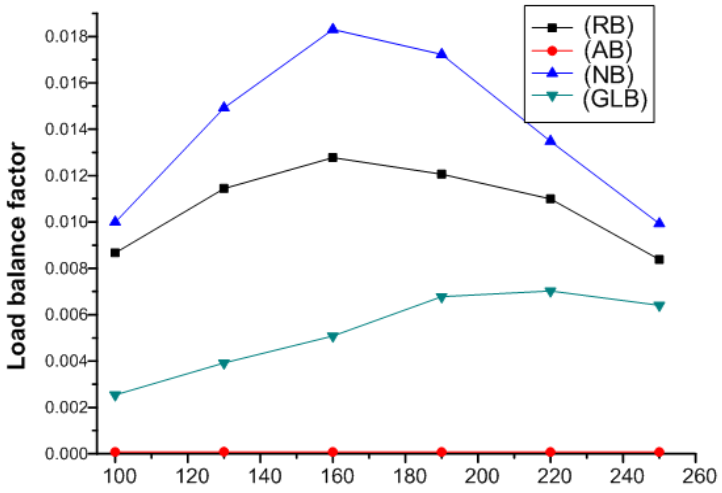
$$f_{ac}(U_m^t, U_c^t, \phi) = \phi \times U_m^t + (1-\phi) \times U_c^t$$

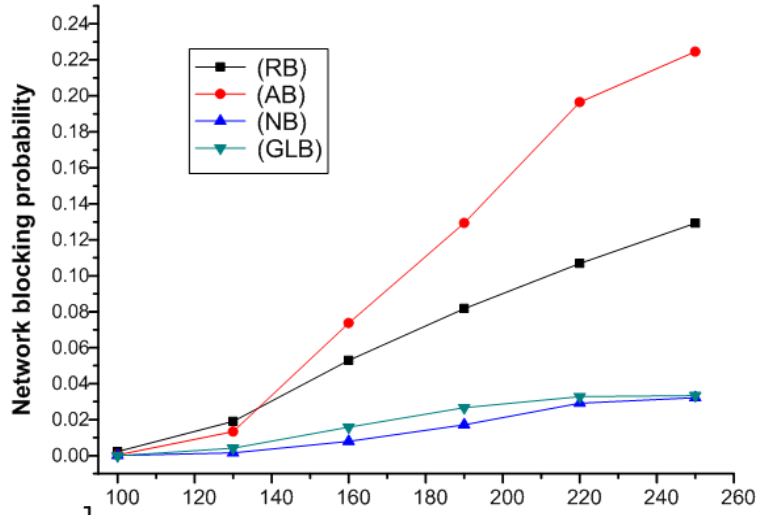
$$f_{bc}(H_p, W_l) = \sum_{l=1}^{H_p} W_l$$

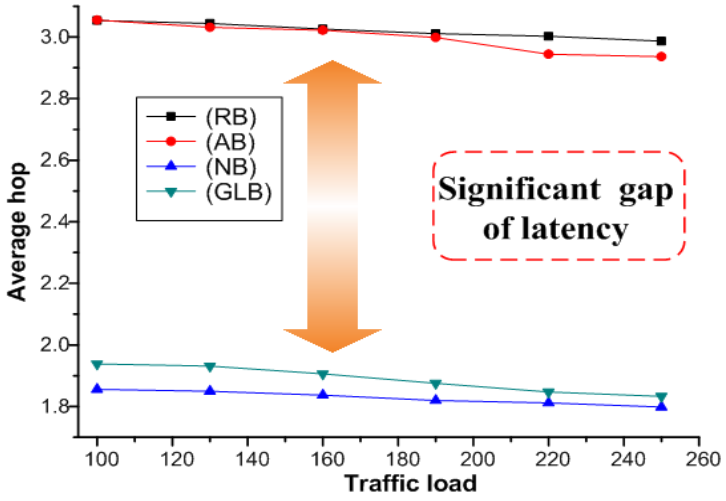
$$\alpha = \frac{f_{\mathrm{ac}}\left(U_m^t, U_c^t, \phi\right)}{\max\{f_{a1}, f_{a2} \cdots f_{ak}\}} \beta + \frac{f_{\mathrm{bc}}\left(W_l, H_p\right)}{\max\{f_{b1}, f_{b2} \cdots f_{bk}\}} (1-\beta)$$

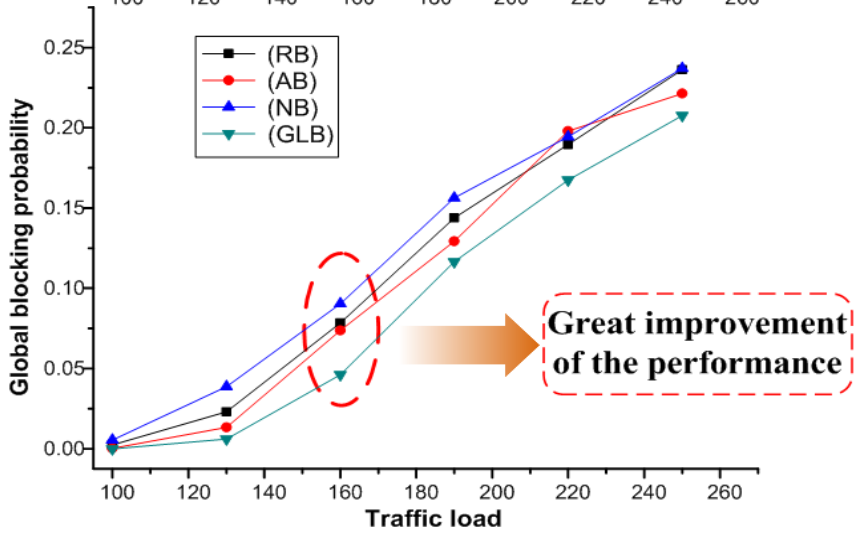
- α **is the joint optimization factor to measure the balance between the network and application resources, which contains the application and network parameters.**
- **Two application parameters, memory utilization** U_m^t **and CPU usage** U_c^t **describe the current usage of data center application resource, while the network parameters are comprised of the TE weight** W_l **of the current link and the hop** H_p **of the candidate path.**
- ϕ **is adjustable proportion between memory and CPU utilization.**
- β **is the adjustable weight between the network and application parameters.**
- **According to application utilization, AC first chooses the best K candidate server nodes in application stratum. In network stratum, the node with minimum** α **value based on the joint optimization factor will be selected from the K candidates. In all schemes, the path will be reserved and setup through signalling protocol between the source and destination node after the choice of the node.**

Performance Results









Charter

The Cross Stratum Optimization (CSO) research group will investigate mechanisms for cooperation between application and network strata with regards to the availability, efficient use of resources, dynamic provisioning, quality of service, and reliability of large aggregates and individual flows of network traffic to and between distributed networked applications.

Initial areas of research include:

- Problem Statement and Baseline Architecture
  - Use cases for cloud/network integration.
  - Development of a general baseline network/application reference architecture and key interfaces
- Joint Optimization Methods and Algorithms
  - Development of virtualization/abstraction/summarization technique for representing both application and network resources.
  - Joint application/network resource allocation and re-allocation.
  - Joint recovery methods and algorithms responding to network failures and/or to data center failures

Relationship to Other Groups

- ALTO (Application-Layer Traffic Optimization)
  - Concerned with optimizing ("better-than-random peer selection") the flows from individual Internet users, while CSO is concerned with the joint optimization of app/network resources.
  - While CSO and ALTO both provide network related information to applications, CSO is also concerned with application layer triggered LSP setup (BoD), and joint recovery in the presence of failures.
  - In addition, CSO is concerned with the large flows either aggregated from many users or between data centers.
- PCE (Path Computation Element)
  - A PCE provides a network centric approach and is useful for optimizing network resources, but not joint app/network resource optimization.
- CCAMP (Common Control and Measurement Plane)
  - Provides network information via route protocols and configuration via GMPLS RSVP-TE. Provides for network equipment oriented interfaces, but not for interfaces to/from application layer.
- SDN (Software Defined Network) BOF
  - Concerned with protocol and interface between application and network.