The Architecture and Traffic Management of Wireless Collaborated Hybrid Data Center Network

He Huang, Xiangke Liao, Shanshan Li, Shaoliang Peng, Xiaodong Liu, Bin Lin
School of Computer Science, National University of Defense Technology
Changsha, China
{huanghe, xkliao, shanshanli, pengshaoliang, liuxiaodong, linbin}@nudt.edu.cn

ABSTRACT

This paper introduces a novel wireless collaborated hybrid data center architecture called RF-HYBRID that could optimize the effect of wireless transmission while reduce the complexity of wired network. RF-HYBRID improves throughput and packet delivery latency through flexible wireless detours and shortcuts, with a comprehensive routing and congestion control method.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design

General Terms

Design, Performance, Management

Keywords

Data center network; wireless technology

1. INTRODUCTION

In this work we propose a novel wireless collaborated hybrid data center architecture that addresses the conflict between network performance and cable complexity with the help of flexible and dynamic wireless transmission.

Several switch-centric tree-based data center networks and server-centric recursively designed data center networks have been proposed which could achieve high throughput with relatively low expense. Nevertheless, with the sheer expanding of data center networks, these new designs often fall short of practicality. Firstly, these elaborately designed topologies often bring along a large amount of new switches and cables, and especially lead to tremendously increased cable complexity. Secondly, the traffic patterns of applications in the data center are difficult to predict, and burst flows often exist that result in hot spots and flow congestion temporarily. Therefore, in view of the worst case, data center networks usually have to be over-deployed. Thirdly, even if the traffic patterns are known in advance, the wired data center network is fixed and not flexible enough to suit every traffic pattern. Fourthly, a large amount of cable bundles behind racks is disadvantageous for the cooling of the system, and cables also face problems of degeneration, space consumption and diagnostic difficulties.

The 60 GHz wireless technology that is now emerging has the potential to provide dense and extremely fast connectivity at low cost. Several works have considered introducing wireless links into data center networks. Flyways [1] utilize the 60 GHz wireless technology to relieve hot-spots in oversubscribed data center networks. Besides, a novel data center design for completely wireless data centers built with cylindric racks is presented [2]. However, neither of them has proposed a practical architectural design for wireless collaborated hybrid data centers. While flyways only consider wireless aided hot-spot mitigation rather than the overall architecture, the completely wireless data center falls short of practicality due to the specific facilities such as cylindric racks.

In our work, we will explore a novel hybrid data center architecture called RF-HYBRID, trying to take advantages of both wired and wireless links to improve the overall system efficiency. RF-HYBRID could largely reduce the cable complexity while preserve the favorable properties of excellent network performance in virtue of flexible wireless links. Nevertheless, several challenges exist for the design and deployment of hybrid network architecture. First, the design space of wireless deployment is large. Hence wireless placement should be carefully determined to construct wireless detours and shortcuts to improve the throughput and latency of the network. Second, since the effective range of wireless links is limited and the signals could be blocked by obstacles, multi-hop indirect routing is needed under some circumstances, while multi-hop routing should be cut down to the utmost extent to improve the overall efficiency. Third, interference avoidance between wireless signals should also be taken into consideration which complicates the general design.

The potential contributions of our work are: (1) we plan to propose a novel efficient hybrid data center architecture which optimizes the utilization of wireless links and reduces the cable complexity. (2) We plan to design traffic-aware topology adapting approaches for wireless links. Specifically, small world shortcuts could be constructed to reduce the packet delivery latency when there is no congestion. On the contrary, when there is congestion, wireless detours could be

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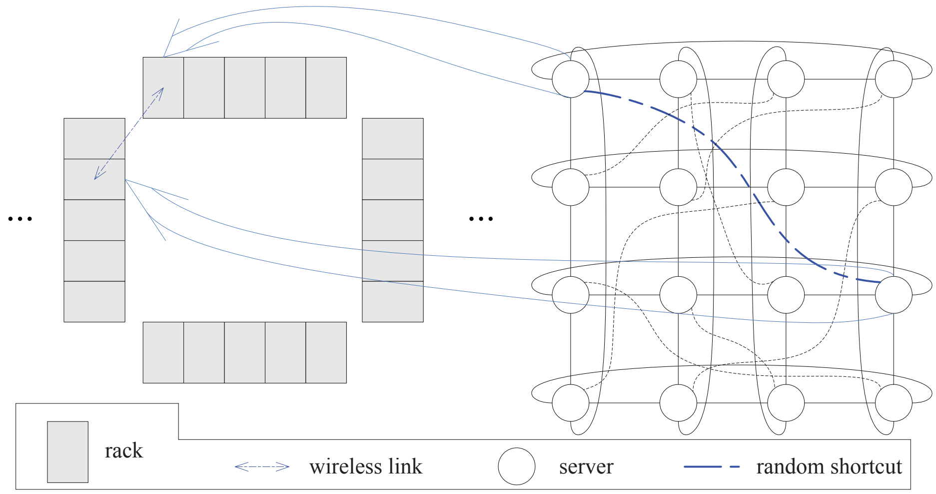

Figure 1: Small world shortcut distribution according to rack physical layout

formed to eliminate hot-spots. (3) We plan to develop a comprehensive efficient routing and congestion control method for the hybrid data center. In addition, the wireless interference model would be built to validate the system design.

2. PROSPECTIVE DESIGN

In this section, the RF-HYBRID architecture of a regular wired network augmented with wireless detours and shortcuts is described, followed by the design of a comprehensive routing and congestion control method.

2.1 Hybrid Data Center Architecture

For the regular wired network, we would rather choose 2D torus over tree-based topology for two reasons. First, 2D torus eliminates the switching fabric and has more regular structure. Besides, when augmented with shortcuts, the torus would obtain small world properties which could largely reduce the network diameter. However, our design of hybrid architecture extends to all kinds of wired data center networks.

The wireless collaborated hybrid data center architecture is arranged as a small world graph when there is little traffic congestion. In order to construct appropriate shortcuts with wireless links, we propose a location-based shortcut distribution approach (see Figure 1). More concretely, when we are setting up random shortcuts between nodes, both their lattice distance in the torus and their physical distance between servers/racks are considered. In other words, as long as the shortcuts are uniformly distributed in the lattice, we can choose the ones with the least physical distances for the convenience of wireless links. Moreover, a novel server/rack layout strategy is also being developed to achieve decreased physical distance between corresponding wireless augmented servers. For example, in Figure 1 we adopt a novel grid-based rack layout rather than the horizontal lane rack layout in order to improve accommodation of concurrent wireless transmissions in limited space of data centers.

2.2 Traffic-aware Topology Adapting

When there is traffic congestion, wireless links could form effective detours to relieve hot-spots [1]. There are three steps to construct wireless detours. First of all, the traffic is estimated and the demands are predicted, and subsequently the hot-spots are located. Afterwards, the wireless detour is instantiated. At last, the routing changes towards the detour to distribute data flows. The adapting topology improves the system throughput under congestion circumstances.

2.3 Routing and Congestion Control

Optimal shortest path routing in large scale small world networks is consuming. Therefore we have to assume greedy geographical routing and hence accept relatively long path length.

A comprehensive routing method which integrates wireless detour routing with the small world network routing is needed. In addition, multi-hop indirect routing should be avoided under both circumstances. Congestion control is mainly done by traffic-aware topology adapting combined with wireless detour routing.

In addition, interference model is required to evaluate and validate the dense deployment of wireless links. D. Halperin [1] gives detailed methods and parameters to model 60 GHz propagation, 802.11ad MAC, directional antennas and data center layouts. The simulations are done using the ns-3 simulator [3].

3. ACKNOWLEDGMENTS

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