Making Cables Disappear: Can Wireless Datacenter be a Reality?

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***Abstract*—Significant portion of the power consumption of datacenter is due to the power-hungry switching fabric necessary for communication. Additionally, the complex cabling in traditional datacenters pose design and maintenance challenges and increase the energy cost of the cooling infrastructure by obstructing the flow of chilled air. In this work, these problems of traditional datacenters are addressed by designing a server-to-server wireless datacenter network (S2S-WiDCN). It is estimated that by implementing S2S-WiDCN, power consumption is lower by five to seventeen times compared to a conventional DCN fabric.**

Keywords—Datacenter; 60GHz; Wireless; server-to-server;

I. Introduction

One of the major challenges of datacenters is the enormous power consumption. As the number of servers within a datacenter grows, the role of the interconnection infrastructure becomes paramount in terms of both energy or power efficiency and performance. Traditionally, datacenter networks (DCNs) are interconnected in tree-based topologies using wired links and multiple hierarchical levels of aggregation. The DCN consumes a significant portion of the total power consumption of a datacenter. The wired network requires power-hungry switches and create large bundles of cables, causing design overheads and maintenance challenges and obstructions to the flow of chilled air for cooling [1]. To address these common design issues faced by wired or cabled datacenters, wireless DCN architectures are being investigated as a promising alternative. Advancements in the 60GHz technologies enable the antennas and transceivers to consume low power and establish multi-gigabit communication channels. Here, we present a server-to-server wireless DCN architecture called S2S-WiDCN based on the 60GHz wireless technology for a small or medium-size datacenter. Through direct server-to-server wireless links using directional antenna arrays, the power-hungry switching fabric of traditional DCNs are eliminated, resulting in significant power savings and resulted in several publications from our work such as [2][3].

II. Related Work

To address issues of datacenters like energy consumption, cabling complexity, scalability, and over-subscription of DCNs, different approaches have been proposed. The most common topology used today in datacenter networks is a fat-tree topology where servers are connected through hierarchical switches. Several alternative wired DCN architectures such as BCube, DCell, DOS, VL2, and Helios have been proposed previously [4]. To improve the performance further, DCNs with optical interconnects have been explored extensively. However, these innovations still rely on copper or optical cables and do not eliminate challenges like high power consumption, high design and maintenance costs due to physical links. To alleviate the issues of DCNs with power hungry switching fabrics and bundles of cables, wireless datacenters with mm-wave inter-rack links are envisioned in research community. Most of the recent works on wireless datacenters propose interconnecting entire racks of servers as units with 60GHz wireless links, primarily in order to utilize the commodity Ethernet switching between servers inside individual racks [5] and use wireless links between Top-of-Rack (ToR) switches [6]. Line-of-Sight (LoS) paths are necessary between the antennas for reliable communication in a wireless datacenter [6]. Cylindrical arrangements of servers have been proposed by Microsoft to create LoS wireless links between servers, which however, requires non-traditional cylindrical arrangement of servers having implications on cooling, server density, and scalability. Our work [2][3] is fundamentally different from the existing wireless DCN architectures as we propose LoS based server-to-server wireless connectivity while maintaining traditional regular rectangular arrangement of server racks.

III. Wireless Datacenter Network Architecture

A. *Wireless Datacenter Network Topology*

In [2], we proposed S2S-WiDCN where the datacenter racks are laid out in the traditional rectangular pattern- adjacent to one another with aisles running between rows of racks. In order to avoid obstruction to the wireless communication links, we establish wireless links only along horizontal lines and vertical planes to communicate between any two servers in the three-dimensional space. To achieve this, each server will be equipped with two high-gain 60 GHz antenna arrays. We propose attaching one of the antennas on the top of the server to enable the communication in the horizontal direction and another one on the back of the server projecting out from the rack to enable communication in the vertical plane. To create LoS, space is required between vertically adjacent servers. To avoid interference and obstructions from the rack frames, communications in the horizontal plane are restricted only to a single line between horizontally aligned servers. Using the beam-steering capability of the antenna array, LoS links between communicating servers can be established with help of a separate control channel as described in [2]. Each server is assigned a unique ID according to its geometric location in order to help determine the beam-steering angles. The angles are precomputed depending on the location of the servers.

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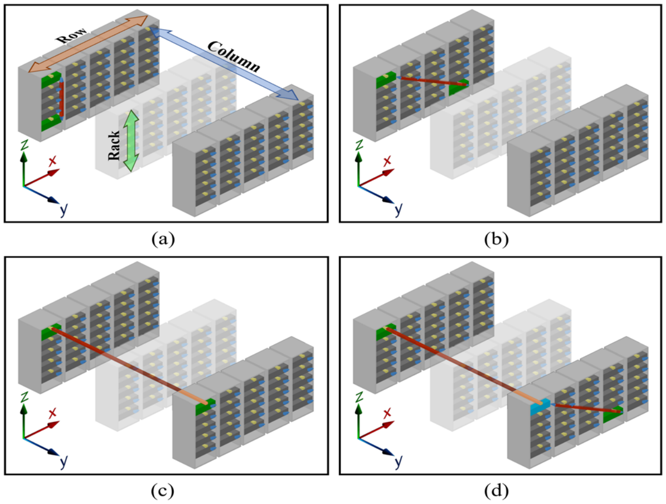

Fig. 1. Possible communication paths between servers situated in (a) same rack, (b) same vertical plane, (c) same horizontal line, and (d) different horizontal lines and vertical planes. Adapted from [3].

B. *Wireless Communication and Routing Protocols*

We adopt the IEEE 802.11ad standard as the 60GHz physical layer protocol for wireless datacenters. The MAC layer protocol establishes as many non-interfering links as possible, greedily on a first-come-first-serve basis until all traffic flow demands are met or all the available Orthogonal Frequency Division Multiplexing (OFDM) channels are exhausted. TCP is used as the transport layer protocol for reliable packet delivery.

To establish wireless connections between servers, *horizontal-first* routing is used as the routing protocol. The server arrangement plays a vital role in the design of this routing protocol. Servers are considered to be arranged in a 3D Cartesian coordinate system with each server having a unique 3D coordinate. Communications in S2S-WiDCN can be broadly classified into two types, i.e., *inter-rack* and *intra-rack* All the intra-rack communications are completed in one hop in the vertical plane [Fig. 1(a)]. Depending upon the relative position of the source and destination servers, three possible scenarios can occur in inter-rack communications. Whether both the source and destination servers are located in the same vertical plane [Fig. 1(b)], or both are in the same column with same height above the ground [Fig. 1(c)], a direct single hop link will be established between the source and destination for data transfer. But if they are in different row and different column, a 2-hop link will be established using an intermediate server [Fig. 1(d)]. As the data travels along the horizontal line first, the adopted routing protocol is referred to as *horizontal-first* routing. In the proposed topology, every server is capable of working as a potential intermediate node.

In [3], we proposed an adaptive routing protocol for S2S-WiDCN, which is capable of routing traffic flows even in the presence of an obstruction in the LoS between two servers. In presence of obstruction, instead of *horizontal-first* routing, *obstruction-avoidance* routing will be adapted to mitigate the effect of the obstruction.

IV. Performance Evaluation and Analysis

We used NS-3 network simulator for evaluating the S2S-WiDCN which supports the characteristics of wireless propagation as well as network-level communications.

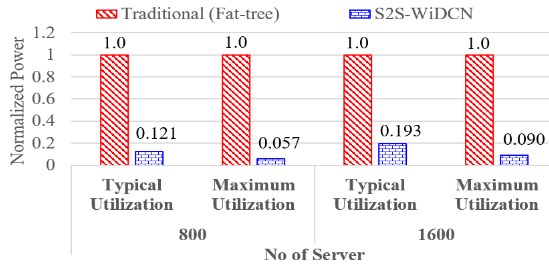

Fig. 2. Normalized power consumption of different architectures. Adapted from [3].

A. *Throughput and Flow Completion Duration*

In [2], we have shown that S2S-WiDCN can support the datacenter traffic for query/response based applications like map-reduce and index-search in both small and medium size datacenters. For both average throughput and average flow completion time, S2S-WiDCN slightly outperforms the traditional fat-tree network due to a fewer number of average communication hop involved. In [3], we also demonstrate that for small scale, S2S-WiDCN can handle multimedia type traffic with bursty flow arrivals without degrading the performance significantly compared to its wired counterpart.

B. *Power Consumption*

A detailed power model for the DCN has been developed in [3] to do the power consumption analysis. Depending on the size and utilization, it is observed [2][3], that compared to traditional wired fat-tree network, S2S-WiDCN can reduce the power consumption by five to seventeen times as shown in Fig. 2 while providing comparable performance.

V. Conclusion and Future Work

In our work, we have demonstrated that S2S-WiDCN can sustain the required performance of a conventional datacenter while reducing significantly reducing the power consumption. Moreover, the challenges in current DCNs such as high design and maintenance cost, huge cabling complexity, inefficient cooling can be addressed by adapting S2S-WiDCN.

In future, we plan to investigate the routing protocol more extensively for the S2S-WiDCN to enhance the robustness and efficiency of the entire system. Furthermore, integration of S2S-WiDCN and consolidation [7] will be investigated.

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