Software Defined Cloud Mini Data Centers – An Effort towards Reduction in Latency of Cloud Traffic Delivery

Mohit Mathur, Mamta Madan

Abstract- In demand to growing traffic of cloud and other web services the vendors are offering several alternatives for timely delivering the traffic. The paper is aims to amass reasons and complexity of delays in regard to end to end delivery of cloud traffic. It further focuses on existing solutions its limitations. The findings of the varying latency suggest that most of the delays are cause due to distance covered by the packet throughout its journey. Hence our solution suggests Software Defined Mini cloud data (SDCmDC) centers distributed throughout the world at different geographical areas instead of having a centralized mega data centers. These mini data centers will be interconnected to each other and carrying data local to their geographical location

Keywords - latency, Software Defined Networking, Cloud Computing, Cloud Traffic, Mini Data center.

I. INTRODUCTION

The amount of data being uploaded and downloaded through cloud data centers is growing rapidly[20]. According to a recent report files worth more than a billion gigabytes are stored on cloud including audio, video, images and documents[30]. With the advent of Internet of things almost every service is going to be cloud 1 dependent whether it is storage, application, computing etc[12]. With the enormous success of cloud adoption and its maturity the expectation from its performance still needs to be tested[29]. The major demands for providing these services are low Cost, high reliability and Low Delay [34]. There is lot of research focused on first and second demand but the third demand i.e. Low Delay which is becoming increasingly essential is still unexplored. The delayed responses to provide cloud services are the main reason of losing users and finally causing revenue loss. When a real time application such as self driving car needs to make decision by consulting one of its cloud servers, it needs to answer fast[31]. Even small delays in such answer could lead to dangerous errors. For example delays in calculations and replies for weather conditions of a geographical area can even cause loss of lives[27]. The main cause of delay in cloud packet delivery is latency. In cloud scenario latency in cloud traffic can be taken as the delay in delivery of cloud packets to destination from original source producing it. However the hindrance in lowering the delay includes a number of factor including server outrages, network congestion, packet loss, virtualization, and many more. The key lies in big server farms where thousands of processors provide solutions. These farms are the centralized data center located at a far geographical area[33]. Moreover, whenever a client needs to access cloud services it has to interconnect the different locations of different servers for computing and data storage. Usually it has to connect at least two sites. Even edge computing network can improve web searching and social networking but not enough sufficient for latency- intolerant applications [13]. The main contributions to latency are described in the next section.

A. The fact file -The Causes and Complexity of latency calculations in Cloud Computing

Calculating latency was much simple before the birth of ubiquitous computing[38]. Before birth of ubiquitous computing, the latency can be simply calculated by looking at the number of hops between sender and receiver and the delays in the packets to reach the destination[28]. At that time the latency is quite predictable. But with cloud the scenario is not so simple, calculating latency is quite complex. In ubiquitous computing like cloud the users are geographically dispersed and accessing the cloud from various devices ranging from laptop to mobile The access path to these devices ranges from high speed fiber lines to 2G Mobile connections. This beauty of cloud comes with a price. The result is horrifying unpredictable latencies. Another aspect is that the increasingly use of Big data applications employ tens or even thousands of compute servers. These servers are geographically distributed around the world, and hence having varying degrees of latency with each of their internet connections. The Cloud Infrastructure further adds a layer of complexity to these latency calculations. This includes the type of network, virtualization, applications, servers, storage fabric and the connection within the data center. The virtualization in network further adds on to these delays. Moreover in virtualization it is difficult to find he faulty service, whether it is server, security or network card. It also depends on the type of cloud users. If the end cloud user is a service provider then the service provider will require deliver the services to its customers and hence require control over the network.

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Mohit Mathur, Assistant Professor, Jagan Institute of Management Studies, Affiliated to Guru Gobind Singh Indraprastha University, India,

Dr. Mamta Madan, Professor, Vivekananda Institute of Professional Studies, Affiliated to Guru Gobind Singh Indraprastha University, India

When packet travels through the network it crosses many repeaters, bridges, switches, routers and gateways[32]. Every network device may contribute to latency. In addition to above a cloud network adds virtualized servers which further increase latency in calculations and processing the requests. Packet fragmentation (if required) at routers is another contributor to latency. Today's traffic is requires quality of services and to provide quality of services the traffic needs to be classified[19]. Classification of cloud traffic types may be another contributor to latency. Larger Routing Paths- The current routing protocols like OSPF (Open Shortest Path First) and BGP (Border Gateway Protocol) calculates optimal routes. But these routes are not optimal as optimal route calculated is not between the actual source and destination. The optimal route is calculated for an n autonomous system. Each autonomous system calculates a part of the complete route between source and destination. Thus the consolidated route is not the optimal one. Routing Protocols that provide foundation of Internet's framework is Border Gateway Protocol (BGP). BGP play a major role in latency, we know that BGP is the only major protocol for calculating optimal routes. But due to load the BGP not always calculate optimal path i.e. alternate more optimal path's that were available are not prioritized. As a result there are delays in delivery due to increased latency. Redundancy can keep it miss the core issue of optimal path calculation. Just as different applications have different tolerances for network latency, the same can be said when it comes to downtime [36]. Applications with varying uptime requirements also commonly reside at different companies or within a company. Some applications may be less critical to the business and can tolerate lower uptime in exchange for lower cost. Other applications cannot tolerate any amount of downtime without resulting in a significant impact on the business another complexity layer lies in the lack of measurement tools for modern applications. While ping and trace route can be used to test Internet connection, modern applications don't have anything to do with ICMP, the protocol behind these tracing devices. TCP's over conservative nature is also responsible for increased latency. TCP retransmissions, connection reset, Error control all leads to increased latency [22]. TCP is not ideally suited for cloud technologies used today [24]. Organizations usually use redundant connections for Internet Connectivity to be always up. Service Providers to provide these redundant connections neglecting core issue - the optimal route to reduce latency. This is another reason of causing latency, jitter and packet loss. The processing of a request is divided into many small tasks, each of which handled by an individual server, and the final response is assembled from the results of these tasks. The results are transmitted as TCP flows that are usually small in size. This results in major part of latency in network traffic.

The traffic inside a cloud data center can be classified as mice flows and elephant flows. Mice flows is the traffic that is generated from interactive applications with short requests and cannot afford high latency while elephant flows are generated from applications that carry heavy traffic such as downloading large files, replication of data etc[10]. Thus small number of elephant flows carries large bytes [7]. The problem lies when these mice flow and elephant flows enter a switch or a router buffer. The small mice flows when queued behind large elephant flows cause a significant amount of queuing delay [9].

Another complication is in identifying the actual infrastructure that is running your cloud applications. Some cloud providers, such as Amazon, don't even want to tell you exactly where their cloud data centers are located (we know that one of their data centers is in Dublin Ireland, but not much more than that for example).

The speed of light is another constraint and its law of physics which cannot be changed. The speed of light in optical fiber is 2/3 of speed of light in vacuum. The distances involved while traveling from one continent to another is significant. If we calculate the actual latency it covers time taken for converting electronic signal to light (for optical fiber).

B. The Impact of Latency

The impact of latency is more on ecommerce and real time services however for services such as email, analytics, etc can tolerate latency up to some extent. According to study reducing latency has more impact on performance than increasing bandwidth. It has been experienced with many big companies that page load time reduces the sales. The real time interactive applications face more impact of latency and leads to failure of application.

II. A LOOK AT EXISTING SOLUTIONS

A lot of efforts were done on reducing latency. Here are the few examples of existing solutions for reducing latency.

A. Cloud Content Delivery Networks

Recently, we find lot of hype in adoption of Cloud Content delivery network (CCDN). The main idea behind content delivery network is to deliver the content without much delay by placing a cache copy at the edge of destination network. These CCDN's are improving day by day as compared to traditional Content Delivery Networks (CDN's).

The figure 1 shows cloud delivery under two scenarios. The figure 1 b. shows, delivery of cloud services without any involvement of Cloud Content Delivery Server. And the part b of the figure shows involvement of CCDN's in delivery of cloud services. When the delivery is without CCDN the services were directly delivered to the customers through ISP's. However when CCDN come in between the Cloud Data center and End user the delivery will be through these CCDN in between. The CCDN Providers claim that the data will be delivered fast through CCDN as they take the advantage of caching. However CCDN's suffer from the some limitations. Firstly, it is appropriate to deliver content which is static in nature using CDN. It is not suitable for content which is produced dynamically. This is typically the case when content is produced, managed and consumed in collaborative activities. Current CDNs do not support applications that involve delivering dynamic content.

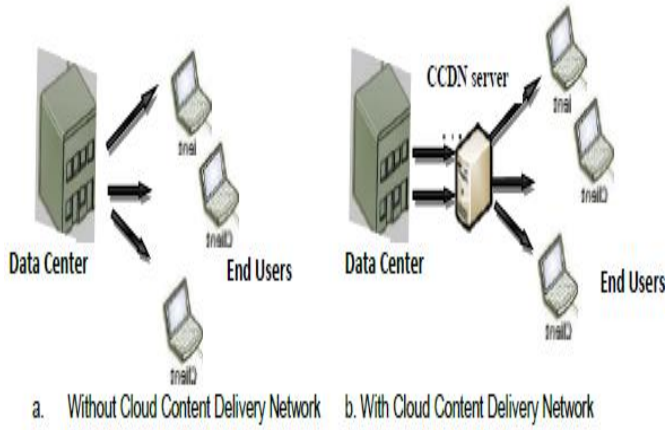

Fig 1: Cloud Delivery with and without Cloud Content Delivery Network

Secondly, Dynamic content cannot be stored on the web server as it is real-time and needs to be constantly updated. Applications that generate content such as data forms on SaaS applications, or playing game applications where user generate dynamic and bi directional traffic need dynamically generated and calculative response from server which cannot be pre stored. Thirdly, CDN relies on caching. Hence updating all cache copies at different geographical location requires time as well as updating further add on to traffic on web which further consumes bandwidth and hence latency for data packets. Fourthly, Additional Cost and management overheads- To deliver packets using CCDN the cloud companies need to pay high to CCDN. Moreover they need to integrate and maintain additional infrastructure including supportive software, Optimization devices etc. Fifthly, the round-trip length makes a big difference when you have dozens of round trips in every transaction. A CDN brings your content closer to your end users; in other words, it reduces the round-trip length. It boils down to having presence in lots of geographical locations around the globe and dynamically serving each content request from the optimal location. It sounds simple, but it's a complicated operational issue that most companies prefer to outsource. Lastly, another limitation is that caching further increases traffic on web which further consumes bandwidth and hence latency for data packets.

B. Providing More Consistent Network Connections

Besides latency, the unpredictable nature of network connections also plays a key role in cloud packet delivery. What is needed is some way to reduce these daily or even minute by- minute variations so you can have a better handle on what to expect. Amazon Direct Connect is an example of managed low latency network. It provides a consistent network, where a dedicated network connection can be established between customer and one of the Amazon Direct Connect locations, rather than having to send all traffic over the public Thus through dedicated connections a cloud provider can easily predict the latency and bandwidth and hence the cloud provider guarantee its quality of services to customers. Similar to Amazon Minisoft Azure also provide hybrid solutions for its cloud services.

C. Task Replication in Cloud Computing

This solution involves replicating each task and then waits for the fastest retrieved copy. But it generally costs additional computing resources, and also increases waiting time in queue for subsequent tasks. We use redundancy to speed-up content download from distributed cloud storage.

D. The Other Existing Solution:

There exist some more solutions like Reliable data center architecture with multiple layers of redundant infrastructure to remove single points of failure. or Optimization of cloud infrastructure (i.e. use of high-performance physical and virtual cloud architectures, and related software technologies) or Optimization of IP traffic through dynamic, intelligent traffic routing mechanism to reduce latency and improve reliability or Optimization of application code for a cloud-based deployment model or Optimization of website coding, and optimized small and large object content or Optimization of IP traffic delivery through TCP acceleration technologies or Optimization of static and dynamic content delivery from the network edge to end-user (i.e. a content delivery network) or Measurement mechanism for performance across the entire "cloud to end-user" system. However none of the solutions mentioned above was successful in solving the required latency problems. They all have their limitations in one or more aspect.

III. A Comprehensive Suggested Solution to Cloud Packet Delivery Latency

Our Solution suggests a comprehensive solution for reducing end to end latency. The solution aims at three basic requirements for reducing latency. First it suggests cloud vendors to develop Mini geographically distributed data centers as the amount of latency increases with distance. The paper suggests software defined infrastructure for these mini data centers and its connected network. The paper then suggests calculating an optimal path between the actual source and final destination. The path does not rely on use legacy routing protocols like BGP and OSPF. It suggests use of open flow protocol and one of its methods called Backward Path Calculation. Another improvement that our paper focuses on is minimizing Traffic delays travelling through the public Internet using optimal transport protocol.

A. Developing Geographically Distributed Software defined Mini Data Centers

Latency is a problem which increases as the distance between sources to destination increases. Whatever technology we apply, the distance including number of hops and a hierarchy of ISP's, CCDN etc play a key role in increasing latency. As volume of data for a geographical location keep on growing the demand of local data center emerges. Mega data centers further increases complexity in calculations and retrieving final results. Request received from far geographical locations carries high network overheads.

As described above, the limitations of cloud content Delivery Network, we do not suggest inclusion of any type of content delivery network outside data centers. Thus instead of developing large data centers at few geographical locations, Cloud vendors should focus on local mini data centers at multiple geographical locations around the world[36]. The idea behind mini data centers is having thousands of datacenters geographically distributed worldwide with few servers each (we leave the number and capacity of servers to data centre designers)[21]. Each group of servers will keep data that local to that geographical area. The mini data centers are few milliseconds away from client devices. However these data centers must be connected together to each other through backbone networks so that retrieving data for mobile devices at a place other than its home location will be possible and preserving the concept of ubiquitous computing. It is important to clarify here that will be no mega data centers in our solution. However a lot of research is going on Cloudlets (Also known as Mini data centers in Fog Computing). Here it is important to differentiate the solution we are proposing from the emerging technology called Fog computing. Fog computing is quite similar, even fog also takes large cloud data centers into consideration and rely on edge devices or mini data centers for processing It includes caching. Fog computing rely on large centralized data centers for high end batch processing. The mini data centers help easy and fast retrieval processing of data within data centers as well as low latency for delivery of data to the end user. The proximity of cloud data centers reduces the role of ISP's and CCDN and hence the cost. It further reduces latency and packet loss. But again rely on mega data center and hence the retrieval of dynamic content to fog servers consists of latency. Hence our solution is little different from what fog computing suggest. Our cloud architecture does not include any mega data center. The architecture consist of mini data centers geographical distributed and connected to its peer data centers and backbone network that carry the traffic make the connectivity to data centers of far geographical areas[18]. Moreover there are many ways in which a cloud vendor can deploy small amounts of data center capacity by using prefabricated modules that are shipped to location.

Figure 2 shows the connectivity of a single software defined mini data centers (SDCmDC) to its local end users. At the core a mini data center, or cloudlet, is a rack of servers available. In Software designed Data center the automation of tasks is achieved by software's. This means the hardware configuration is maintained by intelligent software like Open flow. The infrastructure including storage, networking, security etc in such case is fully virtualized. A software-defined data center separates the application layer from physical layer[25].

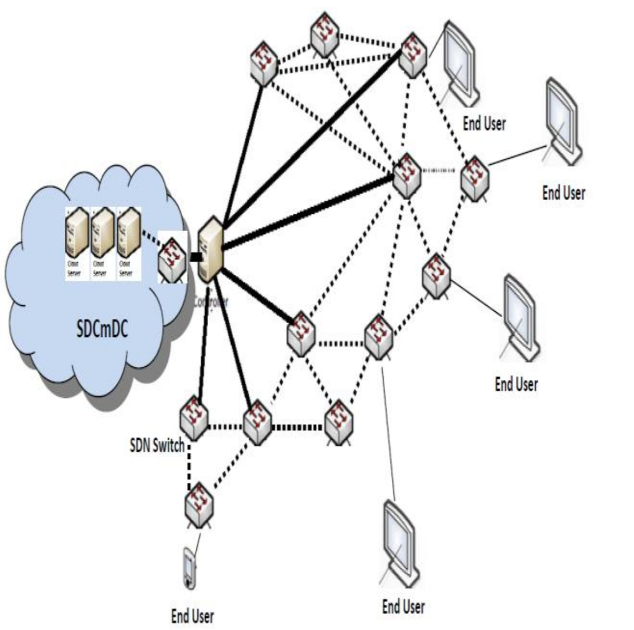

Fig2: A single Software Defined Cloud Mini Data Center (SDCmDC)

The limitation of conventional data centers is that they operate at less than 15 percent of their capacity. Through virtualization and software defining decouple CPU and memory from physical hardware and create pool of resource. A software container Virtual Machine contains virtualized applications and operating system. Each server may run multiple virtual machines simultaneously. This allows higher availability of resources, better performance and hence cost savings. More over we suggest Unified data center management software for managing and centrally monitoring all data centers confined to a geographical area.

These servers carry data and services for its local end users. These types of servers will be available at distributed locations around the world. Each server will be not more than a few milliseconds away from the client devices. These SDCmDC can provide multiple services of multiple cloud vendors simultaneously which means it is multitenant. This end-to-end arrangement allows developers to build new applications and enhance the performance for existing applications. Mini data centers are essential in urban areas where there are heavy data users. The essential equipments of an SDCmDC are server racks, network elements, power system, cooling system, fire suppression, UPS, Power Distribution Units (PDU), and monitoring and management tools built as a single unit. SDCmDC provides benefits such as minimum investment, reduced energy consumption, Speed, reduced latency, modularity, Standardization, Mobility. It allows multiple data centers to set up there server rooms at one place. These SDCmDC have fixed standards of deployment for every cloud vendor. A vendor can easily move it's infra from one SDCmDC to any other SDCmDC.

These highly distributed mini data centers are connected via some type of backbone networks.

Each Mini data center is connected to its end users via software defined networking which classify data and control plane functionality into multiple switches with a controller. Figure 2 shows SDN controller connected to SDN switches forming a network of nodes for delivery within a small geographical area[26]. These mini data centers are located in metro cities connected via Optical backbone networks. Thus local data centers keep traffic local and will not enter the backbone networks. In our solution these data centers deploy Software defined networks instead of traditional router networks because of the unnumbered benefits of software defined networks in comparison to traditional router networks. The software defined network separate data plane from control plane which helps in achieving dynamic network management and connection management with different bandwidth requirements [15]. The traditional networks were human operating, error prone and inefficient. The proposed software defined mini data center architecture carry provisions to scale up and down according to dynamic load requirements. The traffic in the architecture can be classified into intra data center traffic and inter data center traffic. Both the intra data and the inter data connectivity are provided through Optical networks.

In Intra Data center communication, the SDCmDC of a particular domain (a small geographical area) are connected to each other via edge switches of their domain. All the switches under a single SDCmDC are under control of a controller. The suggested distance between SDCmDC of a single domain is approximately 80-100 KM. Each data center may keep 50K-60k servers. The server’s capacity will be as per geographical area covered.

The inter data center communication is depicted in the above figure. Controller keeps the complete information about the paths to its adjacent domains.

By centralizing the network control layers, the companies can flexibly and efficiently manage the network, and also, through dynamic and automated programming, companies can optimize network resources and directly develop the application to manage network resources. The SDN architecture provides APIs for the users to implement customized services for certain purposes: switching, routing, network resource allocation, bandwidth management, traffic engineering, system optimization, quality of service (QoS), security, access control lists (ACLs) and policy management[5]. Also SDN provides bandwidth allocation and QoS change on demand in enterprise or cloud provider network by interacting with the network control layer to query network performance and resource availability.

B. A SDCmDC Architecture and Routing

The routing between SDCmDC is classified as Intra Domain SDCmDC routing and Inter Domain SDCmDC routing. A network region/ country may be viewed as a single domain. The size of domain also depends on the number of users in a small geographical area.

When routing is provided between multiple SDCmDC in a domain (in adjacent geographical area) it is called Intradomain routing. Figure 3 shows Intradomain connectivity among mini data centers. When routing is provided between data centers of different domains across different geographical area it is called Intradomain routing.

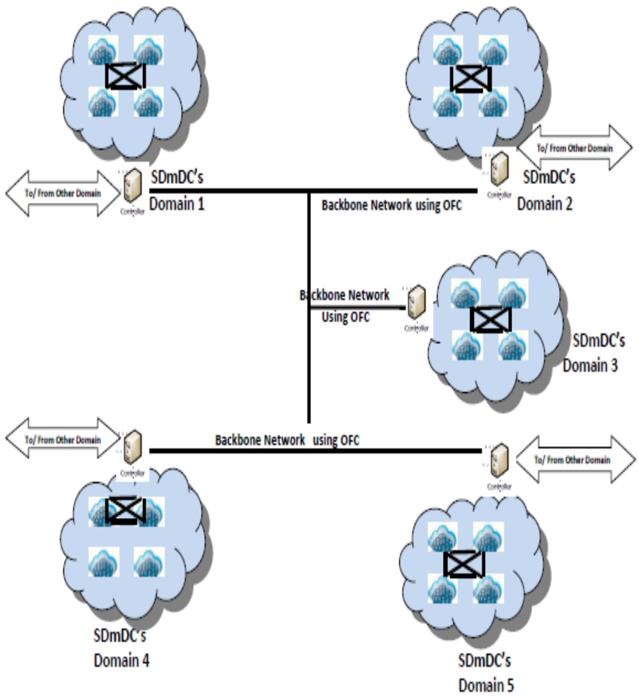

Fig 3: Intradomain Connectivity of SDCmDC in a confined geographical area

Figure 4 shows Interdomain connectivity among geographical distributed mini data centers of different domains. We assume that each SDCmDC is lead by a controller of software defined network. A controller manages number of switches under its domain.

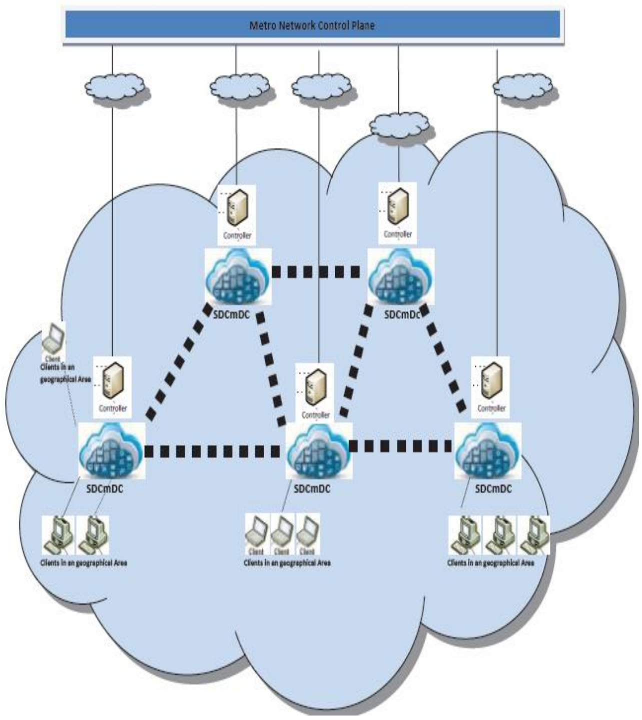

Fig 4: Interdomain Connectivity of SDCmDC in different geographical locations around the world

C. Routing between SDCmDC using SDN backward Recursive Path Computation

The traditional IP based networks rely on single routing domain. The reason of single routing domain calculation in IP network was that the vendor/ISP does not disclose its routing information. When the path goes out of the routing domain from ingress node to egress node, the solution fails as the path was computed considering a single domain. Hence the routing information from source to destination across multiple domains will be done independently by each domain [17]. Thus the complete calculated route from source to destination is not an optimal one. In comparison in the SDN based routing open flow protocol present in controller can directly handle the data transmission path and can easily calculate the complete path between sources to destination across multiple domains. SDN can calculate routing information in real time scenario [11]. We assume that the Controller in Software defined Cloud Mini Data center 1(SDCmDC1) will share its routing information with Controller of SDCmDC 2 within its domain. We suggest Backward Recursive Path Method for path computation among source to destination. In Backward Recursive path technique the path computation is based on all paths between the domains and the path computation in neighboring domain including the destination[6]. Here the module that calculates optimal path plays a key role. This path computing module of controller can support in calculating topology based network path [6]. Here, the path computation starts from source domain, as shown in Figure below, and the neighboring Path Computing modules of controller are notified of the group of available paths. The request for optimal path computation is forwarded between these modules of different controllers of one domain to another till the controller of destination network is not reached. The destination controller domain builds a tree of optimal path rooted at destination and pass back to initial controller domain in reply. Each controller adds an optimal path from destination to source of its domain in the tree. The figure5 shows connection between Software defined cloud mini data center a cloud user. The routing will be performed by controllers of different domain. These controllers calculate optimal path of their domain and share it in backward direction towards the source i.e. SDCmDC from the cloud user.

Based on the received information, each of the controllers computes the optimal paths from the ingress node to the egress node and forms a tree starting from the destination. The controller of domain E will send this calculate path information back to domain C which then also calculate optimal path and will send it back in the tree to controller of domain A and back to SDCmDC. This will be helpful for availing cloud service from remote data center when the local data center cannot provide the service. Usual scenario will be when the devise moves from its residential geographical area to far geographical area. In that case the cloud services will be fetched from its home geographical data center.

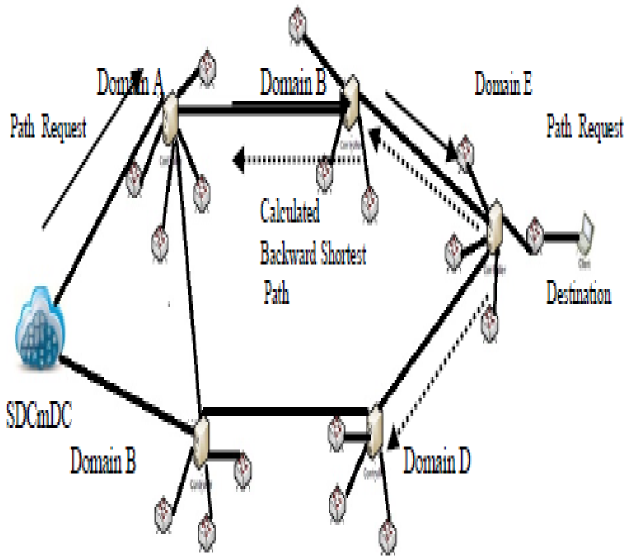

Figure 5: Backward Path calculation between different domains

IV. Conclusion

As per study and research, the main culprit behind increasing worldwide cloud traffic is the distance between the client and cloud data center which further lead to latency in cloud traffic. Hence it's essential to limit the traffic to geographical boundaries and speed up the delivery within stipulated time. Developing mini data centers focusing on local cloud service delivery is the only solution for latency problems. Our research does not end with the above suggested model. The research continues with developing new algorithms, devices and methods for software defined mini data centers delivery.

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AUTHORS PROFILE

Mohit Mathur, a true academician is an Associate Professor, Department of Information Technology, JIMS, Delhi, India. He Completed his Graduation from Delhi University and Masters from National Institute of Electronics and Information Technology, Department of Electronics, Ministry of Information Technology, India. Mr. Mathur carries 18+ years of experience in academia, teaching Graduates, Post Graduates and Industry Professionals. He is a professional member of international organizations such as ISOC, AASCIT, IAENG, UACEE, IGI Global and carries deep interest in the area of Cloud Computing, Software Defined Networks and Security. His research work focuses on Traffic optimization for cloud computing. His publications covers different aspects of cloud like security, traffic management, scalability, migration, network management, etc.

Professor Mamta Madan is an accomplished professor of Computer Science. She started her journey in academics by graduating with B.Sc (Hons) Physics from Delhi University with excellent academic record and was awarded by National Graduate Physics Society Association at Delhi University for getting first position in the college. She further studied at Jamia Milia Islamia and holds dual Master degrees, in Computer Application (MCA) and Business Administration (MBA). Further in her pursuit of education she completed her Master of Philosophy (M.phil) and Doctoral research (P.hd.) in Computer Science from Banasthali Vidyapith – Rajasthan.Prof. Madan has over 16 years of experience in research and academics. She is associated with VIPS since inception. In recognition of her contributions in academics, Prof. Madan was honoured with the Best Teacher Award at VIPS in the year 2008-2009. During her tenure with VIPS, she also contributed significantly and spearheaded the training and placement cell for many years. Many placement drives were organised at VIPS under her guidance and students were placed in SAP, Infosys, Computer Science Corporation, HCL Technologies, Wipro, I Gate etc. Dr. Madan is also member of NAAC committee and Academic Council at VIPS.She is actively involved in research in the areas of artificial intelligence, software engineering, data mining and cloud computing. She is guiding different Ph.D students enrolled at various Indian universities. She is associated with many professional and research bodies like Central Board of Secondary Education, Computer Society of India etc. Her expertise goes well beyond the classroom, as she is in the panel of examiners at various universities and has evaluated numerous projects of computer science. She has published and presented many papers in National and International Journals of repute.