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List of Abbreviations/Symbols

List of symbols used in Chapter 1	
Notation	Definition
STP	Spanning Tree Protocol
TRILL	Transparent Interconnection of Lots of Links
RIP	Routing Information Protocol
ICMP	Internet Control Message Protocol
OSPF	Open Shortest Path First
SDN	Software Defined Networking
API	Application Programming Interface
VoIP	Voice over Internet Protocol
SLA	Service Level Agreement
ForCES	Forwarding and Control Element Separation
TCP	Transmission Control Protocol
LLDP	Link Layer Discovery Protocol
TLV	Type Length Value
FIFO	First-In-First-Out
QoS	Quality of service
S_i	i^{th} switch in the network
T_{total}	Total time taken by the probe packet through the link and back to the controller
$T_{ctrltoS_1}$	Delay from the controller to switch S_1
$T_{ctrltoS_2}$	Delay from the controller to switch S_2
$Delay_{S_1toS_2}$	Link delay
MTU	Maximum transmission unit
tc	traffic control
SDN_c	SDN-controller port
$non - SDN_c$	Legacy port
MAC	Media Access Control
gARP	Gratuitous Address Resolution Protocol
ARP	Address Resolution Protocol
RTT	Round Trip Time

List of symbols used in Chapters 2 & 3	
Notation	Definition
SLA	Service level agreement
$E_1, E_2, E_3,$ and E_4	Events in the network
S_i	i^{th} switch in the network
k_i	Number of interfaces in switch S_i
I_i^j	j^{th} interface of switch S_i
MCPS	Maximum Coverage Polling Scheme
AFPS	Adaptive Fine-Grained Scheme
DAPR	Dynamic Adjust and Periodical Reconstruction
SWT	Sliding Window Based Tuning
QoS	Quality of Service
FIFO	First-In-First-Out
STP	Spanning Tree Protocol

RSTP	Rapid STP
WFQ	Weighted Fair Queueing
PQ	Priority Queueing
f^k	Flow
SF_i	Set of flows going through switch S_i
f_i^l	l^{th} flow going through i^{th} switch, where $1 \leq l \leq SF_i $
$IN(f_i^l)$	Ingress interface for flow f_i^l at switch S_i
$sent(f_i^l)$	Number of packets sent for flow f_i^l by switch S_i
C_{ij}^l	Number of packets of l^{th} flow present in the channel connecting switch S_i and switch S_j
Q_{iq}^l	Number of packets of l^{th} flow queued in q^{th} queue of switch S_i for transmission
$OUT(f_i^l)$	Egress interface for flow f_i^l at switch S_i
$recv(f_i^l)$	Number of packets received for flow f_i^l by switch S_i
$drop(f_i^k)$	Number of packets of l^{th} flow dropped before queuing
M_1, M_2	Marker 1, Marker 2 respectively
Δ_{real}	Actual packet loss
Δ_{meas}	Measured packet loss
BFS	Breadth First Search
CBR	Constant bit rate
λ	It is the measure to compare the consistency achieved by different methods
OVS	Open vSwitch

List of symbols used in Chapter 4

Notation	Definition
SDNs	Software-defined Networks
QoS	Quality of Service
TX	Transmit
TC	Traffic Control
ICMP	Internet Control Message Protocol
NIC	Network Interface Card
RX	Receive
DMA	Direct memory access
qdiscs	Queueing disciplines
HTB	Hierarchical Token Bucket
CBQ	Class Based Queueing
TBF	Token Bucket Filter
SFQ	Stochastic Fairness Queueing
RTT	Round trip times
L	Average number of packets in the queue
λ	Average arrival rate
W	Average waiting time
t_1 and t_2	two consecutive polling epochs
λ_{av}	Average rate of arrival of packets in the queueing system
$qlen_{av}$	Average queue length
\bar{W}	Average waiting time for packets in the queue
$\overline{qlen}(t_1, t_2)$	Mean queue length in the interval $[t_1, t_2]$
$\bar{\lambda}(t_1, t_2)$	Mean arrival rate of the packets in the interval $[t_1, t_2]$
$\bar{W}_{qlen, \bar{\lambda}}(t_1, t_2)$	Mean waiting time of a packet in the queue in the interval $[t_1, t_2]$

tx_packets	transmitted packets through the queue
$qlen_{t_1}, qlen_{t_2}$	Queue lengths at time t_1 and t_2 respectively
$[t_0, t_1], [t_1, t_2], \dots, [t_{m-1}, t_m]$	m consecutive estimation intervals
$\overline{D}_{qlen, \lambda}(t_1, t_2)$	Estimator for the mean link delay $\overline{D}(t_1, t_2)$ in the interval $[t_1, t_2]$
C	Calibration constant
f_c	Cut-off frequency
b	Transition band
N	Length of the filter

List of symbols used in Chapter 5

Notation	Definition
QoS	Quality of Services
SLA	Service Level Agreement
SDN	Software Defined Networking
NRMSE	Normalized Root-Mean-Square Error
SWT	Sliding Window Based Tuning
m_t , and m_T	minimum and maximum polling interval time respectively
Δ	Threshold
t_i , and t_d	Factors by which we increase or decrease the polling intervals respectively

List of symbols used in Chapter 6

Notation	Definition
SDN	Software Defined Networking
API	Application Programming Interface
ISP	Internet Service Provider
IGP	Interior Gateway Protocol
OSPF	Open Shortest Path First
LSAs	Link-state Advertisements
ACL	Access Control List
BGP	Border Gateway Protocol
MAC	Media Access Control
UDP	User Datagram Protocol
SD-WAN	SDN in a Wide Area Network
iBGP	Internal Border Gateway Protocol
RCP	Routing Control Platform
DEFO	Declarative and Expressive Forward Optimizer
SDN_c	SDN-controlled
SCTs	Solitary Confinement Trees
HNM	Hybrid Network Manager
ILP	integer linear programming
VM	Virtual Machine
OVS	OpenvSwitch
HAL	Hardware Abstraction Layer
CHPL	Cross-Hardware Platform Layer
HSL	Hardware-Specific Layer
IBSDN	IGP-as-a-Backup
gARP	gratuitous ARP

OSPF	Open Shortest Path First
SNMP	Simple Network Management Protocol
LLDP	Link layer discovery protocol
TCP	Transmission Control Protocol
ACC	AutoConfClient
ACS	AutoConf Server
ISC	Intermediate Switch Configurator
GPIA	Generic Path Inconsistency Avoider
TE	Traffic Engineering
SOTE	SDN/OSPF Traffic Engineering
DAG	directed acyclic graph

List of symbols used in Chapter 7	
Notation	Definition
gARP	gratuitous Address Resolution Protocol
ARP	Address Resolution Protocol
SCT	Solitary confinement tree
STP	Spanning Tree Protocol
GNS3	Graphical Network Simulator-3
ACL	Access Control List
DNS	Domain Name Server
C_i	Indicates i^{th} core switch in the network
D_i^j	Indicates a legacy distribution switch, such that D_i^j is j^{th} distribution switch of i^{th} core switch
$A_{i,j}^k$	Indicates an access switch, such that $A_{i,j}^k$ is k^{th} access switch of D_i^j distribution switch
$h_{i,j}^{k,l}$	Indicates a host machine l connected to $A_{i,j}^k$
SDN_i^j	Indicates an SDN switch at distribution layer, such that SDN_i^j is the j^{th} SDN distribution switch of i^{th} core switch
D_{pt}	Indicates diversion point
$N_P(N_1, N_2)$	Indicates a native path between node N_1 and node N_2 in the network
$EP(N_1, N_2)$	Indicates extended path between node N_1 and node N_2 in the network
S_c	Number of core switches
S_d	Number of distribution switch pairs
S_a	Number of access switches connected to one distribution switch pair
A_h	Number of hosts connected to one access switch
T_a	Percentage of total traffic resolved at access layer
T_d	Percentage of total traffic resolved at distribution layer
T_c	Percentage of total traffic resolved at core layer
HA_{load}	Load on the links in host-access layer
AD_{load}	Load on the links in access-distribution layer
DC_{load}	Load on the links in distribution-core layer
N	Total number of distribution switches.
S	Total number of SDN switches at distribution layer
L	Total number of legacy switches at distribution layer
A_{plen}	Average path length of all traffic
AT_{plen}	Average path length of access traffic
DT_{plen}	Average path length of distribution traffic

CT_{plen}	Average path length of core traffic
SDN_{dc}	SDN Distribution-Core link
$Legacy_{dc}$	Legacy Distribution-Core link
$P(D_X)$	Probability that packet of a given traffic type X is diverted for waypoint enforcement
DP_{plen}	Diverted path length
NP_{plen}	Native path length
$AT_{plen}, DT_{plen},$ and CT_{plen}	Average path lengths of access traffic, distribution traffic, and core traffic, respectively
$P(D_a), P(D_d),$ $P(D_c)$	Probability of divergence of access layer traffic, distribution layer traffic, and core layer traffic, respectively
P_{WPA}	Percentage of waypoint enforcement achieved
$P_{SDN_switches}$	Number of packets going through the SDN switches
P_{total}	Total number of packets in the network
LBNL	Lawrence Berkeley National Laboratory