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Extensions to FreeBSD Datacenter TCP for Incremental Deployment Support

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DCTCP has been available since FreeBSD 11.0!!

FreeBSD DCTCP highlight

- What is the average transmission time of 10 800KB transfers while 2 long flows are running in the same link?
  - TCP (NewReno): 252.7 msec
  - **DCTCP: 82.5 msec**
  - **One-sided DCTCP: 89.4 msec**

Using BSD DCTCP achieves faster data transfer than using TCP not only in the fully deployed network but also in the partially deployed network.

Outline

1. DCTCP introduction
   - What is DCTCP?
   - What benefit can you receive by using DCTCP?
   - Necessary network equipment for DCTCP
2. FreeBSD DCTCP feature
3. How to configure DCTCP on FreeBSD

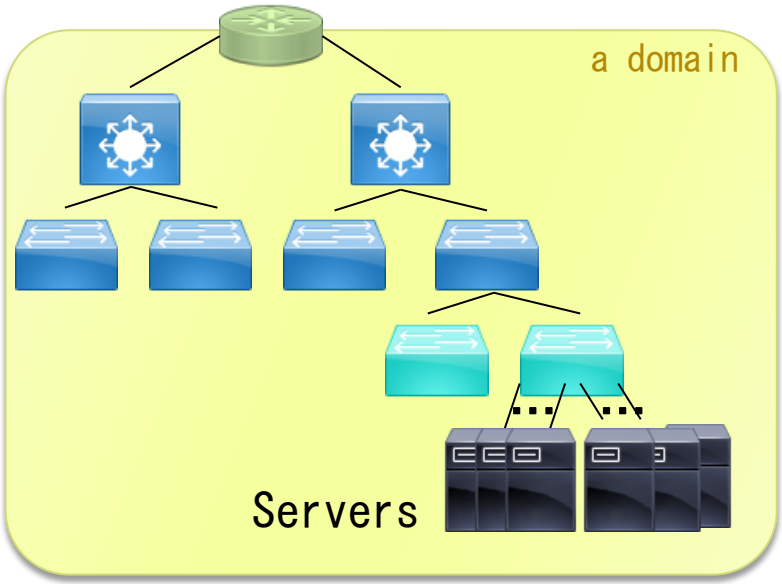
DCTCP (Datacenter TCP) [*]

- A proposed TCP variant that solves performance impairments in the data center network
- Traditional TCP problem
  - Concurrent interactive short flows show long data transmission time in a traffic mix of short flows and long flows
    - Short flows: database query and response
    - Long flows: bulk transfer for server migration
- DCTCP contribution
  1. Maintain low and predictable latency for short flows
  2. Absorb traffic bursts
  3. Maintain high throughput for long flows

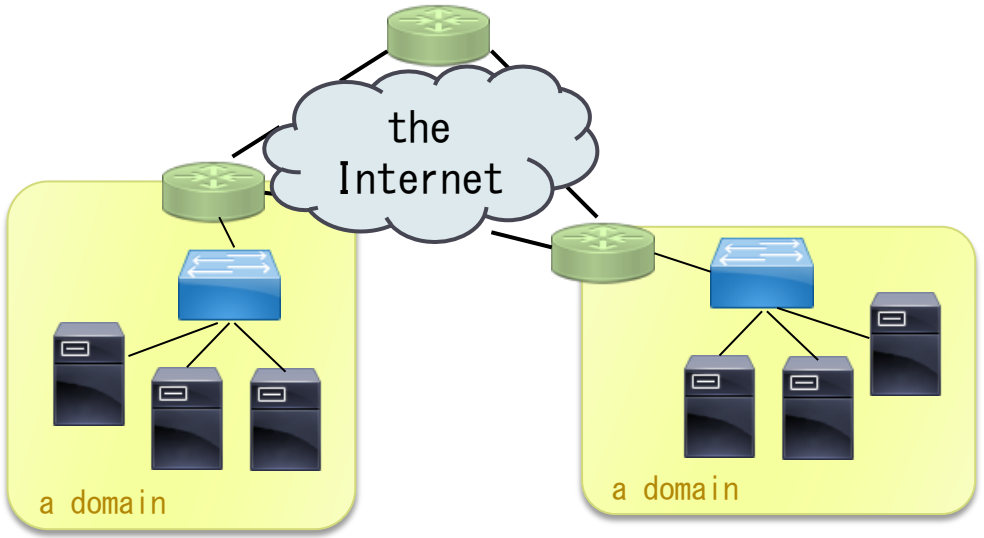
[*] M. Alizadeh et al. “Data Center TCP (DCTCP)”. In Proc. ACM SIGCOMM. 2010, pp. 63-74.

Data Center Network

Data Center Network



The Internet

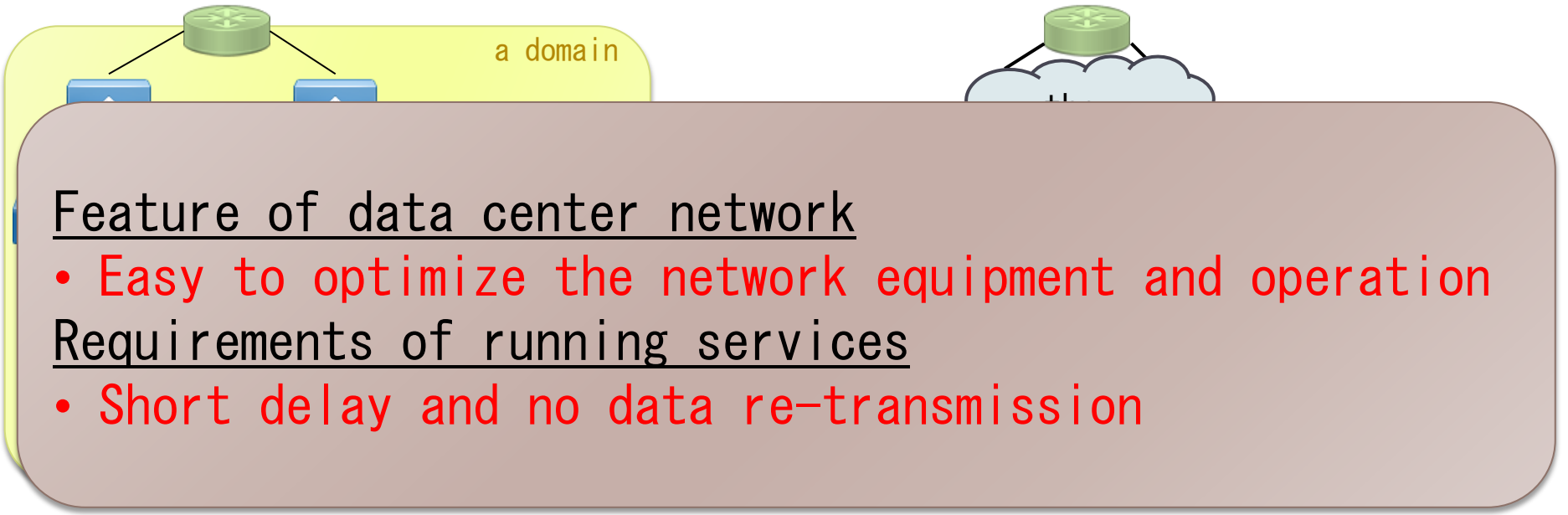


	Data center network	The Internet
Where is the destination host?	Single domain	Multiple domains
Sensitive to what?	Data transmission time	Throughput

Data Center Network

Data Center Network

The Internet



Feature of data center network

- Easy to optimize the network equipment and operation

Requirements of running services

- Short delay and no data re-transmission

	Data center network	The Internet
Where is the destination host?	Single domain	Multiple domains
Sensitive to what?	Data transmission time	Throughput

DCTCP approach

- Leverage ECN (Explicit Congestion Notification) to the network

ECN (Explicit Congestion Notification)

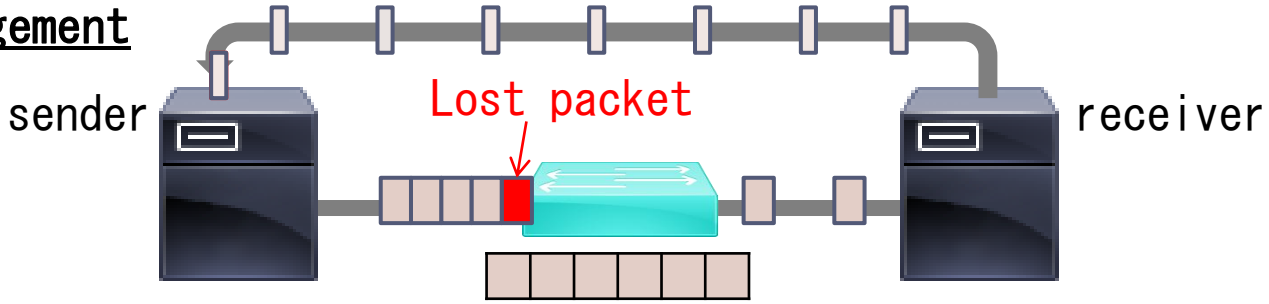
- ECN is a traditional active queue management scheme
  - Provide auxiliary information for TCP congestion control
- ECN motivation
  - make hosts transfer data without packet losses
- Network equipments supporting ECN are needed
  - L3 switches/routers and servers
    - Check the configuration of network equipments
    - Many of servers unset ECN as default

ECN mechanism

Traditional queuing management

Window size calculation with a packet loss

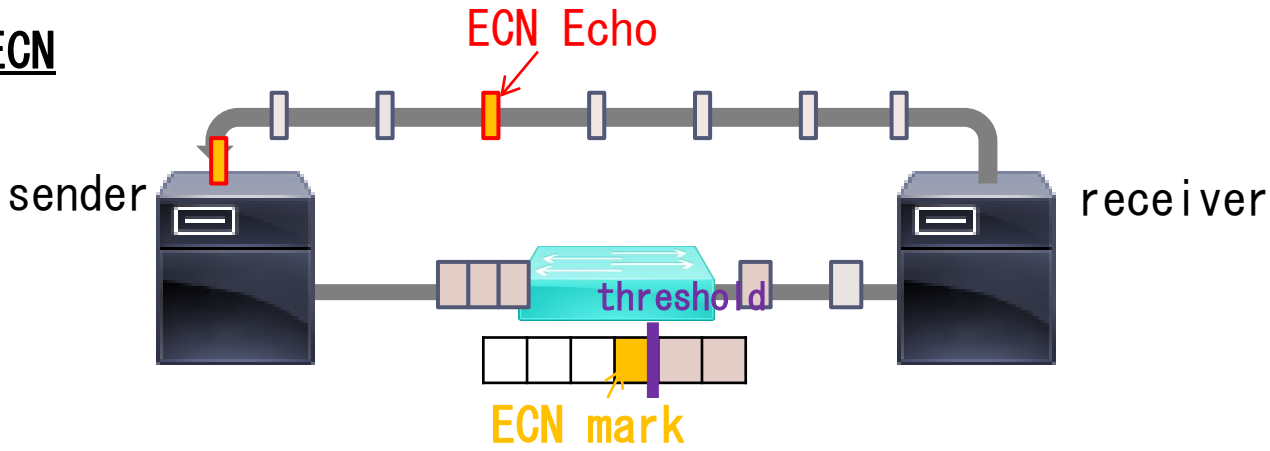
W <- W / 2



Queuing management with ECN

Window size calculation with ECN reception

W <- W / 2



- L3 switch
  - Set ECN when the queue length exceeds the threshold
- Sending hosts
  - Halve the window size by receiving a ECN packet
    - Window size: the total amount of data in byte sent by the host

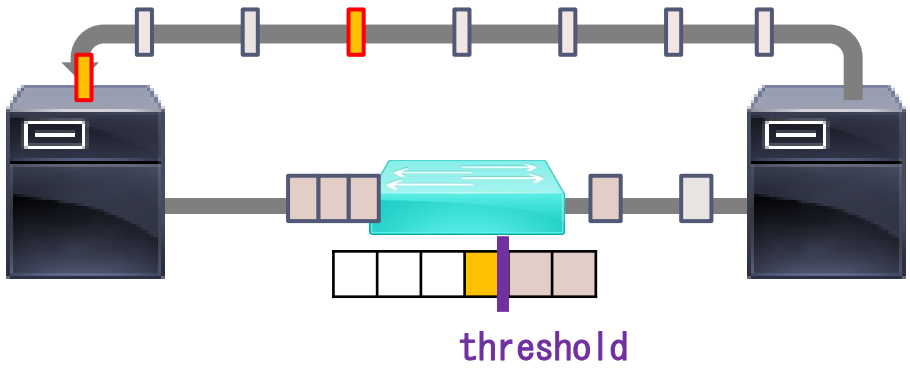
DCTCP mechanism

- Use ECN for the precise estimation of the potential congestion

- L3 switch
  - Set ECN when the queue length exceeds the threshold
- Sending hosts
  - Calculate the window size based on the fraction of ECN in a previous window size

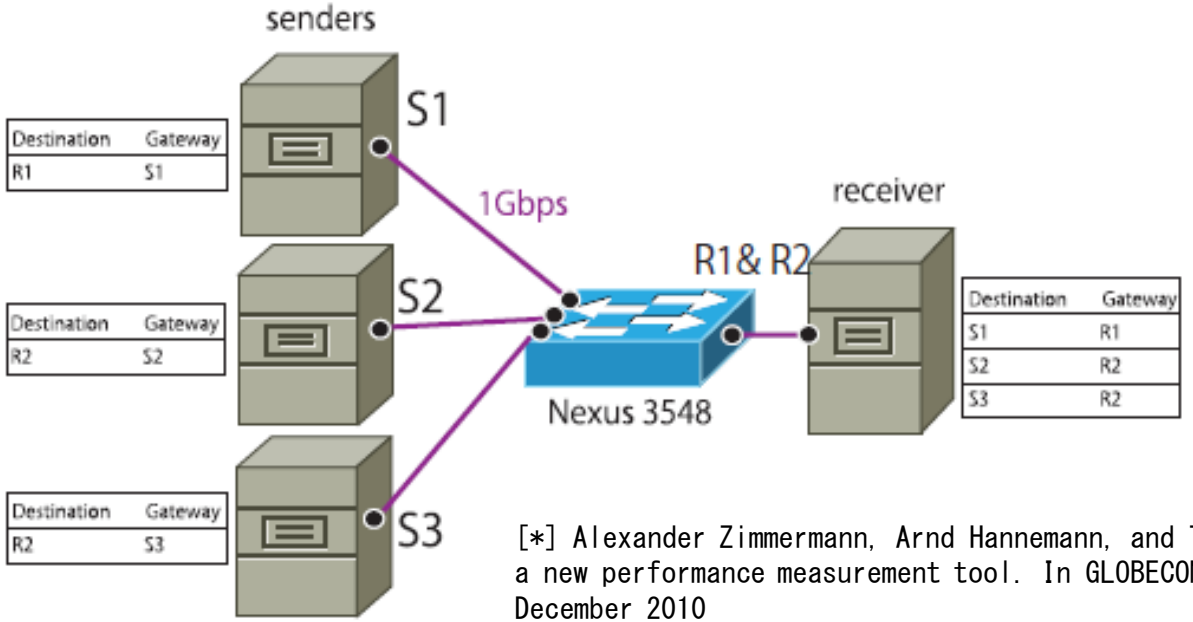
Window size calculation
with ECN reception

F <- frac. Of ECN pkts in W
W <- W * F / 2



Testbed

- Hosts: four x86 machines
  - FreeBSD-CURRENT 10.0
  - Two dual-core Intel Xeon E5240 CPUs @ 3 GHz
  - 16GB RAM
  - Four ports Intel PRO/1000 1G Ethernet card
- L3 Switch: Cisco Nexus 3548
  - Threshold of queue length: 10packets
- Traffic generator: flowgrind [*]

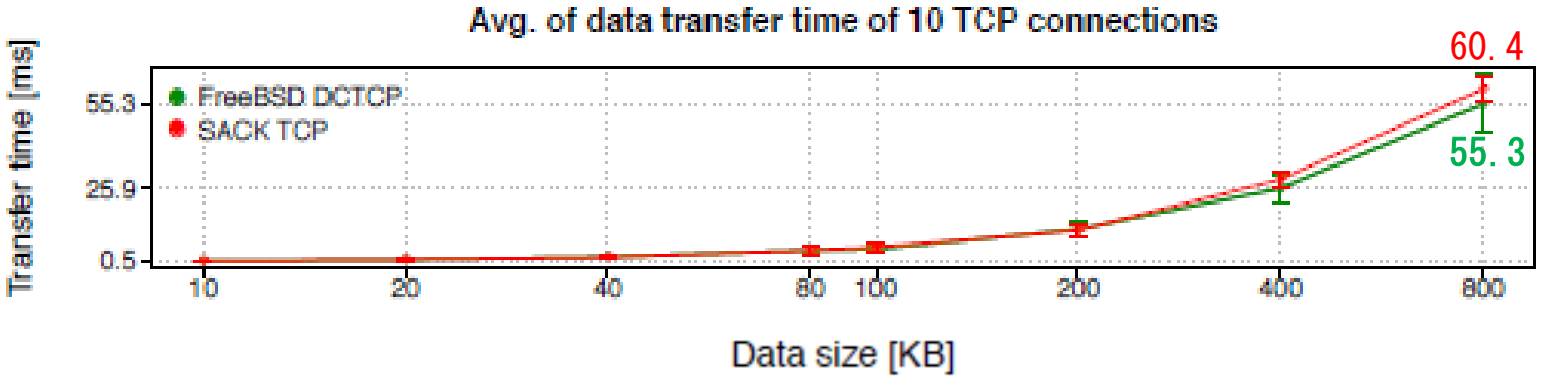


[*] Alexander Zimmermann, Arnd Hannemann, and Tim Kosse. Flowgrind – a new performance measurement tool. In GLOBECOM, pages 1-6. IEEE, December 2010

Experiment

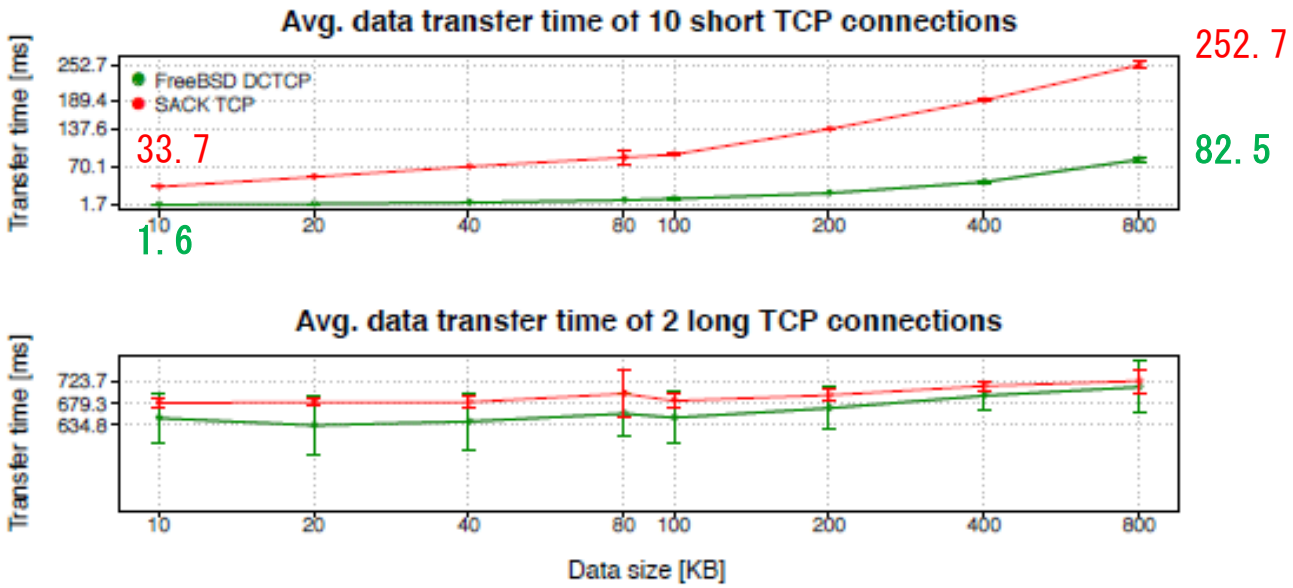
- Incast
  - Objective: evaluate the TCP/DCTCP performance of burst transfers
  - Scenarios: run 10 flows simultaneously
    - Transfer size: 10 - 800KB
  - Metric: avg. of data transmission time for short flows
- Bulk transfer
  - Objective: Evaluate the TCP/DCTCP performance by running a mix of short and long flows
  - Scenarios: starts 10 short flows 500 milliseconds after 2 long flows run
    - Transfer size of short flows: 10 - 800KB
    - Transfer size of long flows: 40MB
  - Metric: avg. of data transmission time for short and long flows

Result of Incast experiments



- DCTCP flows reduce 5 milliseconds of data transmission time at most

Result of bulk transfer experiments



- With background flows running, DCTCP short flows reduces
  - 10KB transfer time by 32.1 milliseconds
  - 800KB transfer time by 170.2 milliseconds

Summary of DCTCP

- Q. What is DCTCP?
- A. DCTCP is a proposed TCP variant using ECN for data center network

- Q. What benefit can you receive by using DCTCP?
- A. You can reduce 170 milliseconds of data transmission time for 800KB transfer in a mix traffic of short and long flows

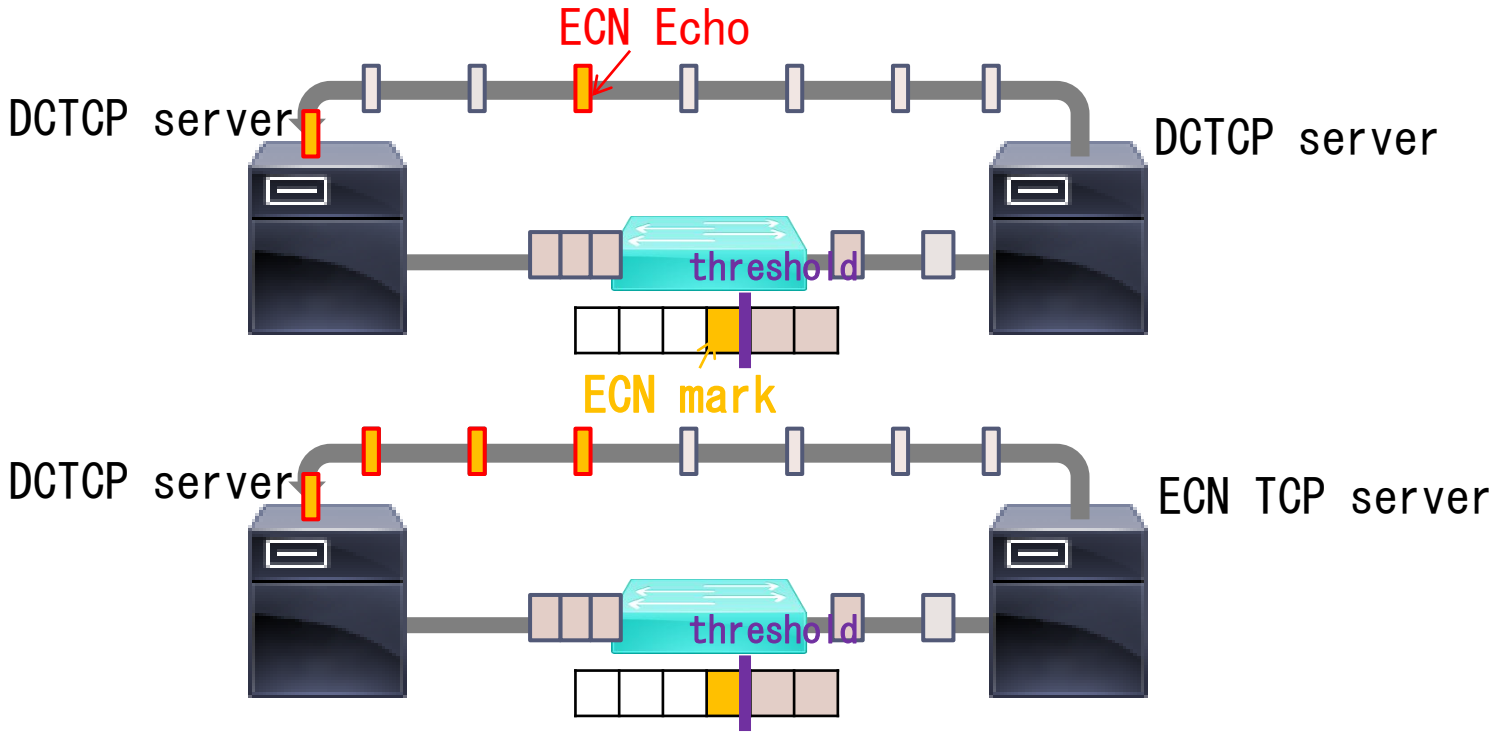
- Q. What are necessary network equipments for DCTCP?
- A. L3 switch, routers and servers supporting ECN

BSD DCTCP = DCTCP + α

α means

1. Incremental deployment support
2. Initial window size calculation for performance tuning

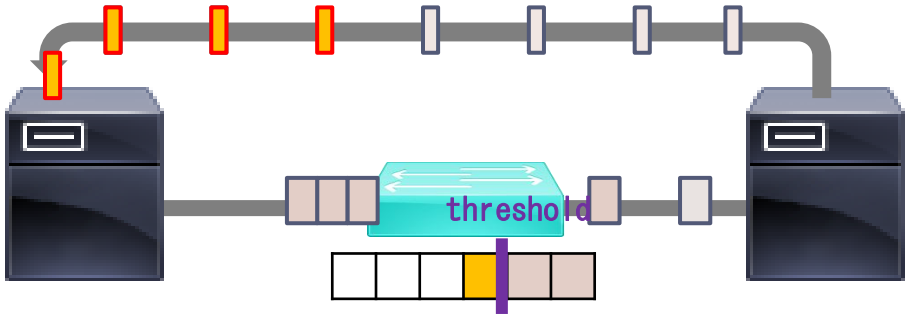
Why is incremental deployment support important? [1/2]



Q. Do you recognize the difference between two example?
A. YES for us **but NO for servers**

Why is incremental deployment support important? [2/2]

DCTCP server (e.g., application server)



ECN TCP server (e.g., appliance servers)

- Using DCTCP on a one-sided server is a possible situation in the network where appliance servers are running

BSD DCTCP for incremental deployment

- One-sided DCTCP Problem
  - (worst case) Trans. Time of one-sided DCTCP >> trans. Time of two-sided DCTCP
- Solution
  - Support compatibility with ECN
    - See our paper for detail
- Result
  - One-sided DCTCP remarks 90% of similar performance to two-sided DCTCP
    - Incast: +0.09 milliseconds
    - Bulk transfer: +6.9msec milliseconds

BSD DCTCP for initial window size calculation

- Selectable parameter considering the trade-off between latency and throughput

	slowstart = 0	slowstart = 1 (recommended[*])
Benefit	• Higher throughput	• Short latency during data transmission • Friendly to competitive running flows
Flaws	• Unfriendly to competitive running flows	• Longer data transmission time

[*] Stephen Bensley, Lars Eggert, Dave Thaler
"Microsoft's Datacenter TCP (DCTCP): TCP Congestion Control for Datacenters"
IETF, draft-bensley-tcpm-dctcp-03.txt

How to configure DCTCP on FreeBSD

1. Load DCTCP module
   ```
   # kldload cc_dctcp
   ```
2. Check available congestion control algorithms
   ```
   # sysctl net.inet.tcp.cc.available
     newreno, dctcp
   ```
3. Enable ECN
   ```
   # sysctl -w net.inet.tcp.ecn.enable=1
   ```
4. Enable DCTCP
   * Support for incremental DCTCP deployment is included
   ```
   # sysctl -w net.inet.tcp.cc.algorithm=dctcp
   ```
5. Tune DCTCP parameter (optional)
   - For faster data transfer (default)
     ```
     # sysctl -w net.inet.tcp.cc.dctcp.slowstart=0
     ```
   - For short latency
     ```
     # sysctl -w net.inet.tcp.cc.dctcp.slowstart=1
     ```

Summary of BSD DCTCP

BSD DCTCP = DCTCP + α

- BSD DCTCP minimizes the performance penalty even in the partial use
- BSD DCTCP has an optional configuration considering trade-off between latency and throughput

Acknowledgement

Many thanks to

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  - Hiren Panchasara
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