Multipath bonding at Layer 3

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mami

measurement and architecture for a middleboxed internet

measurement | architecture | experimentation

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Overview

- **Motivation**

  Operator's demand for aggregation of DSL and mobile capacity
- **Layer 3 Bonding Solution**

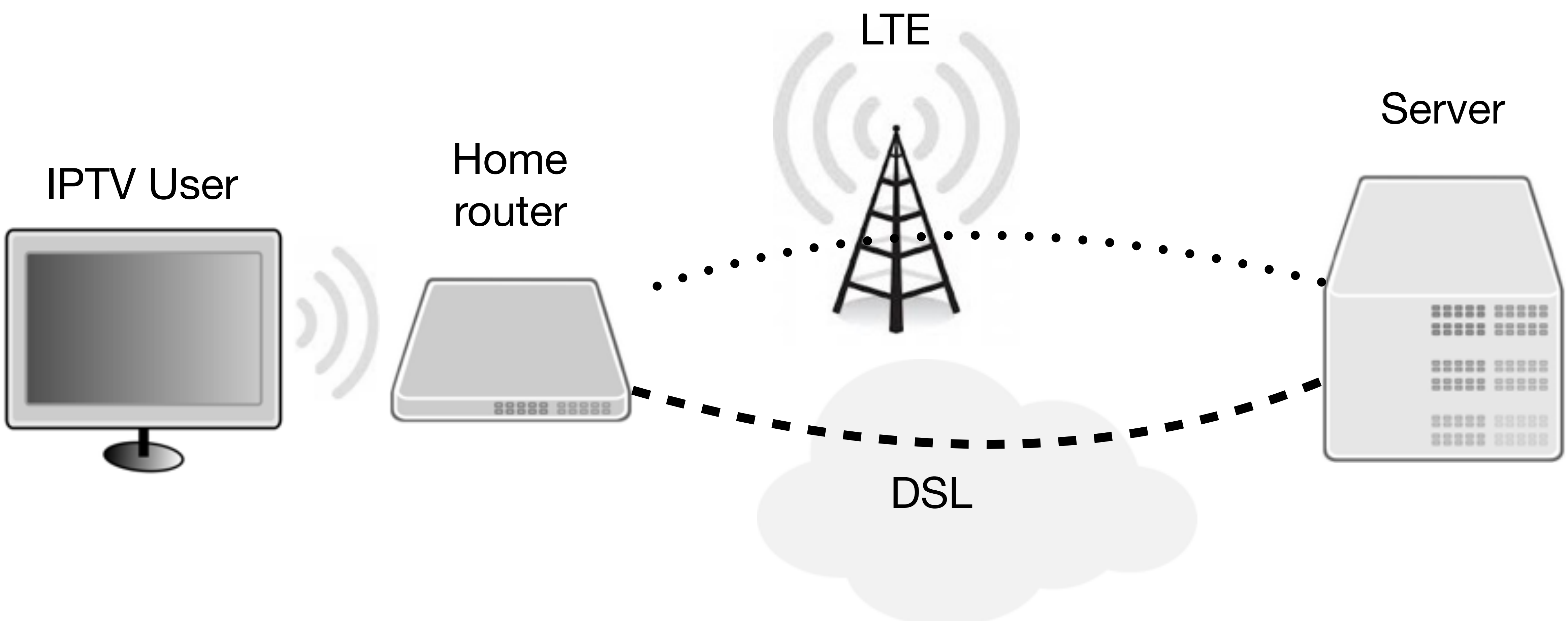
  Architecture and Scheduling Algorithm
- **Implementation**

  Packet mangling, scheduling, and re-ordering
- **Evaluation**

  Single Flow and TCP cross traffic
- **Conclusion**

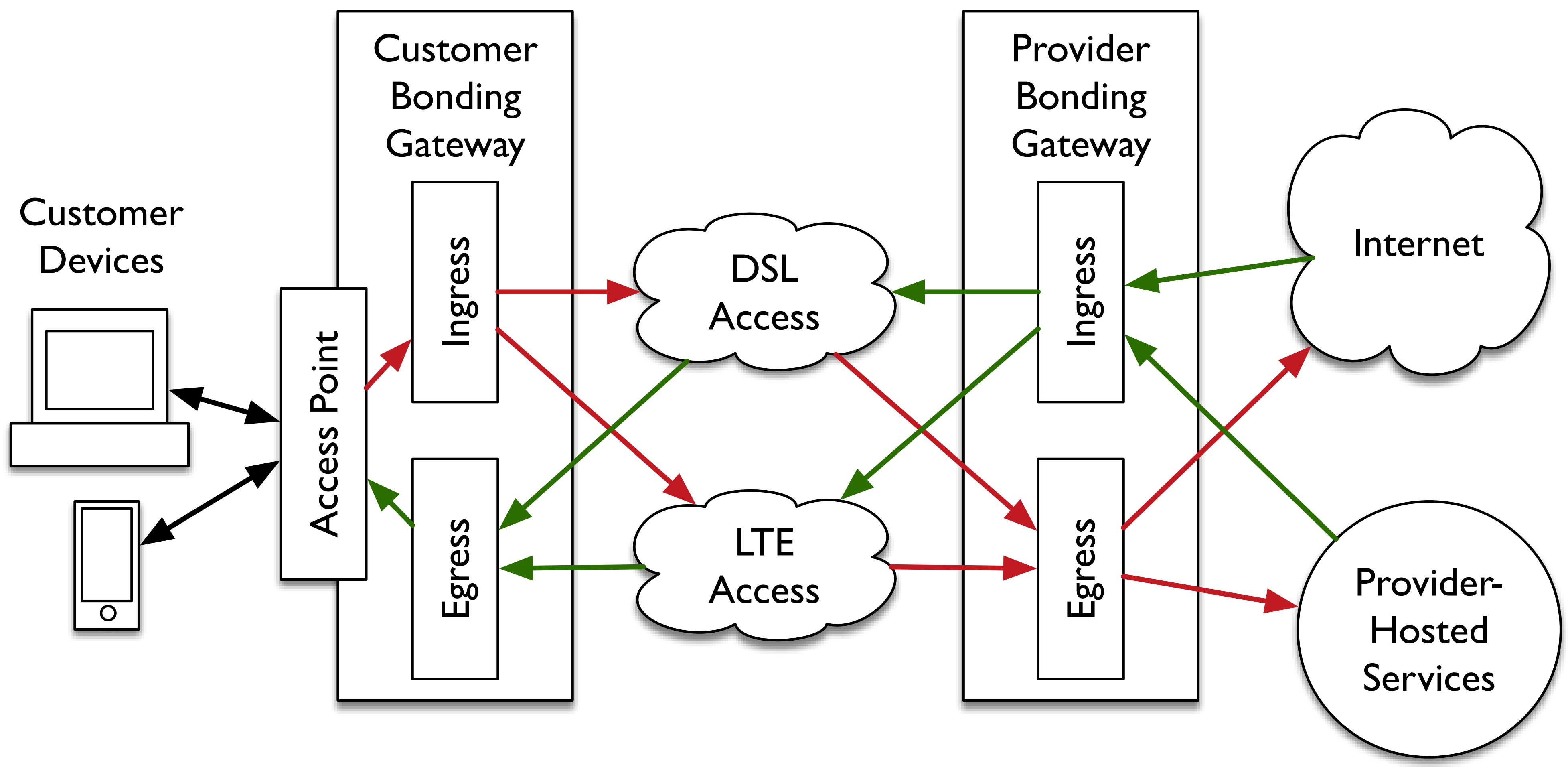
  Works but further work needed…!

Motivation: Aggregation of DSL and mobile capacity



- DSL capacity is not sufficient to e.g. serve HD video service
- MPTCP proxy only suitable for TCP traffic

Bonding Architecture: Costumer and Provider Bondings Gateways



- **Ingress:** accepts traffic, schedules transmission & adds SEQ#
- **Egress:** takes traffic from bonding interface, re-orders & strips SEQ#, sends loss report to ingress

Scheduling Algorithm: Adaptive Weight Increment (AWI)

Goal: fill fixed link first, use mobile link for excess traffic demand only

AWI using Weighted Round Robin (WRR)

- fixed weight for fixed line: $w_{fixed} = 50$
- dynamic calculation for mobile line (initially $w_{mobile} = 0$):

$$w_{mobile} += k * \frac{pkt_{lost}}{pkt_{sent}} * w_{fixed}$$

control parameter

Scheduling Algorithm:
Initial Weight Increment (IWI)

Goal: react quickly when congestion is arising

If $w_{mobile} = 0$ & loss is reported:

increases w_{mobile} by the number of lost packets

Note: w_{mobile} is clamped to a maximum value $w_{mobilemax} = 50$

Scheduling Algorithm: Delayed Weight Decrement (DWD)

Goal: shift load back to the fixed line without inducing loss by shifting the load too quickly

If no loss reported for T_{dwd}:

decrement w_{mobile} by one for each interval $T_{report} = 50ms$

Note: We investigate different values for T_{dwd} but it must be a multiple of T_{report} (as loss reports are only received every T_{report} milliseconds)

Implementation: Bonding Ingress

intercepts packets using Netfilter queues (in `OUTPUT` chain) and forward to userspace

- **Packet Mangling**
  - Control packets from the egress (loss reports) will be discarded
  - Data packets: sequence number added & forwarded for scheduling
    - Generic Routing Encapsulation (GRE) Sequence Number and Key fields could be used
- **Scheduling**
  - Decides about netfilter mark (`fwmark`) to map data packet to the right output queue using `iptables`
  - Counts the number of packets sent on each interface (pkt_{sent})

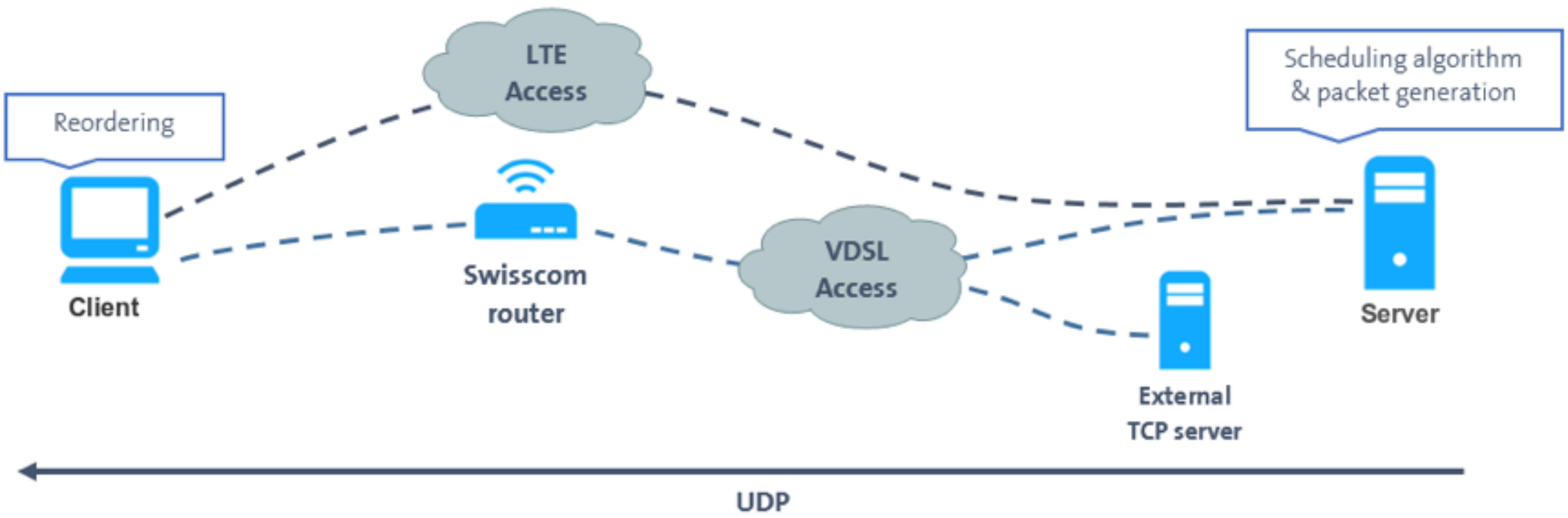
Implementation: Bonding Egress

intercepts all incoming UDP packets using Netfilter queues (in PREROUTING chain)

- **Re-ordering**

  1. New packet received:
     - ***forward*** packet directly *if SEQ# = last_accepted + 1* (or the first of a new flow) and update last_accepted
     - ***enqueue*** packet *if SEQ# > last_accepted + 1* (and remember timestamp)
     - ***discard*** packet *if SEQ# < last_accepted + 1* (as it has been assumed to be lost)
  2. Further check other packets in queue (and update last_accepted):
     - ***forward*** first packet in queue *if now last_accepted + 1 = SEQ#* of queued one
     - ***forward*** also *if now -* T_{dwd} *> timestamp* (missing packet is assumed to be lost)

Evaluation: Experimental setup



- Two Linux Debian Wheezy machines (client & server)
- 1492 bytes UDP packets (28 bytes UDP/IPv4 header, 4 bytes for SEQ#, and 1460 bytes of dummy payload)
- TCP cross traffic: file transfer from a public server (cdimage.debian.org) with 50ms to client
- DSL link is shaped to a maximum rate of 64 Mb/s and stable 13ms delay (measured)
- Swisscom's Huawei E3276s LTE stick with about 60Mb/s (and variable delay of 25 - 45ms)

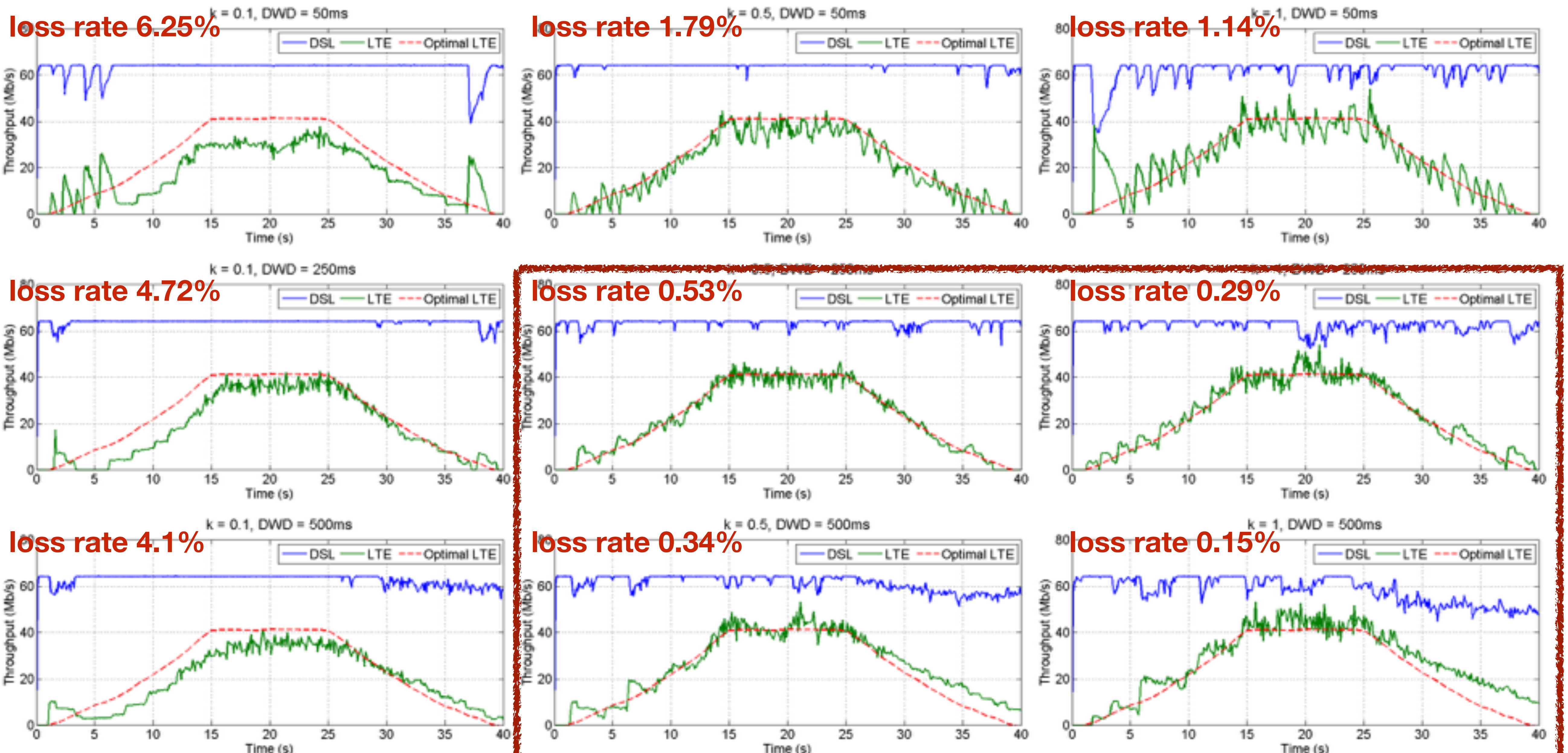
Evaluation:
Results for a single flow

k=0.1 k=0.5 k=1

T_{dwd}=50ms

T_{dwd}=250ms

T_{dwd}=500ms

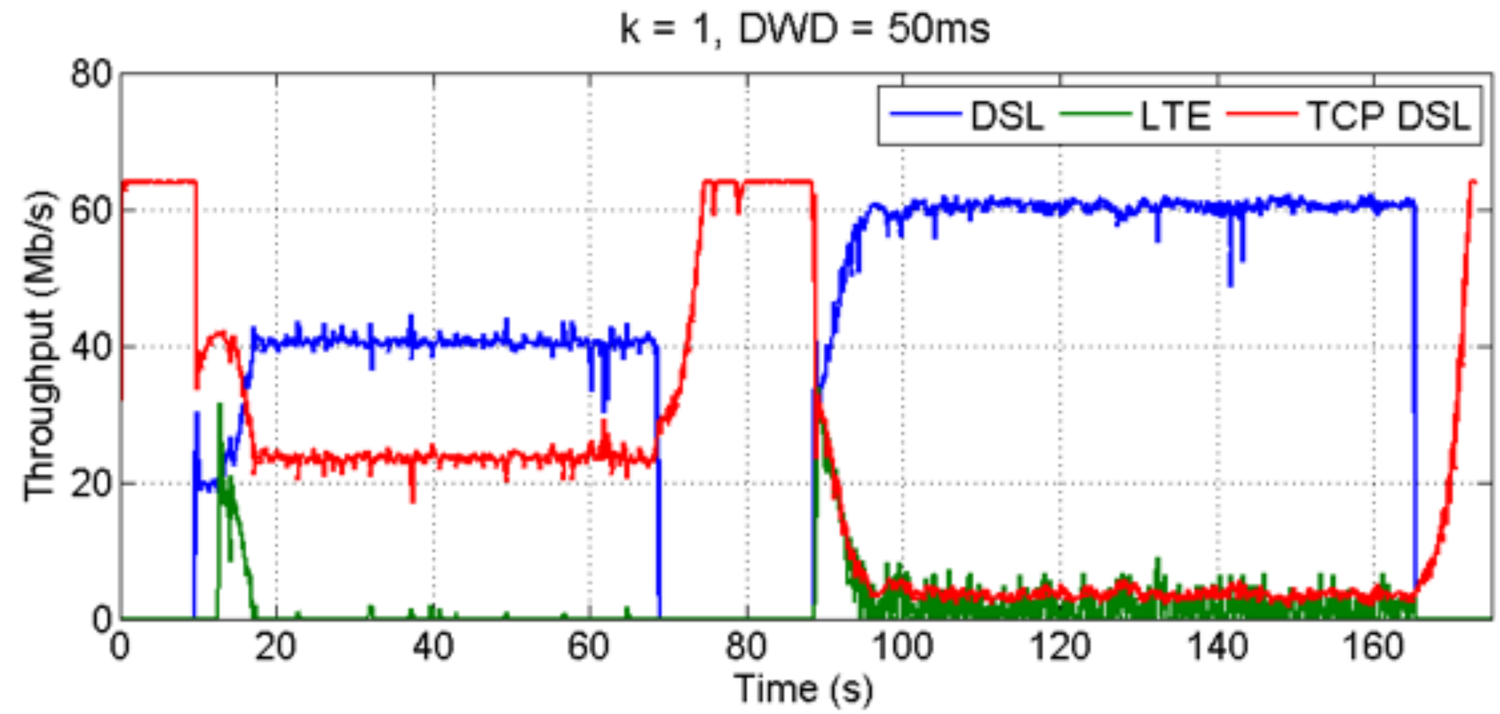


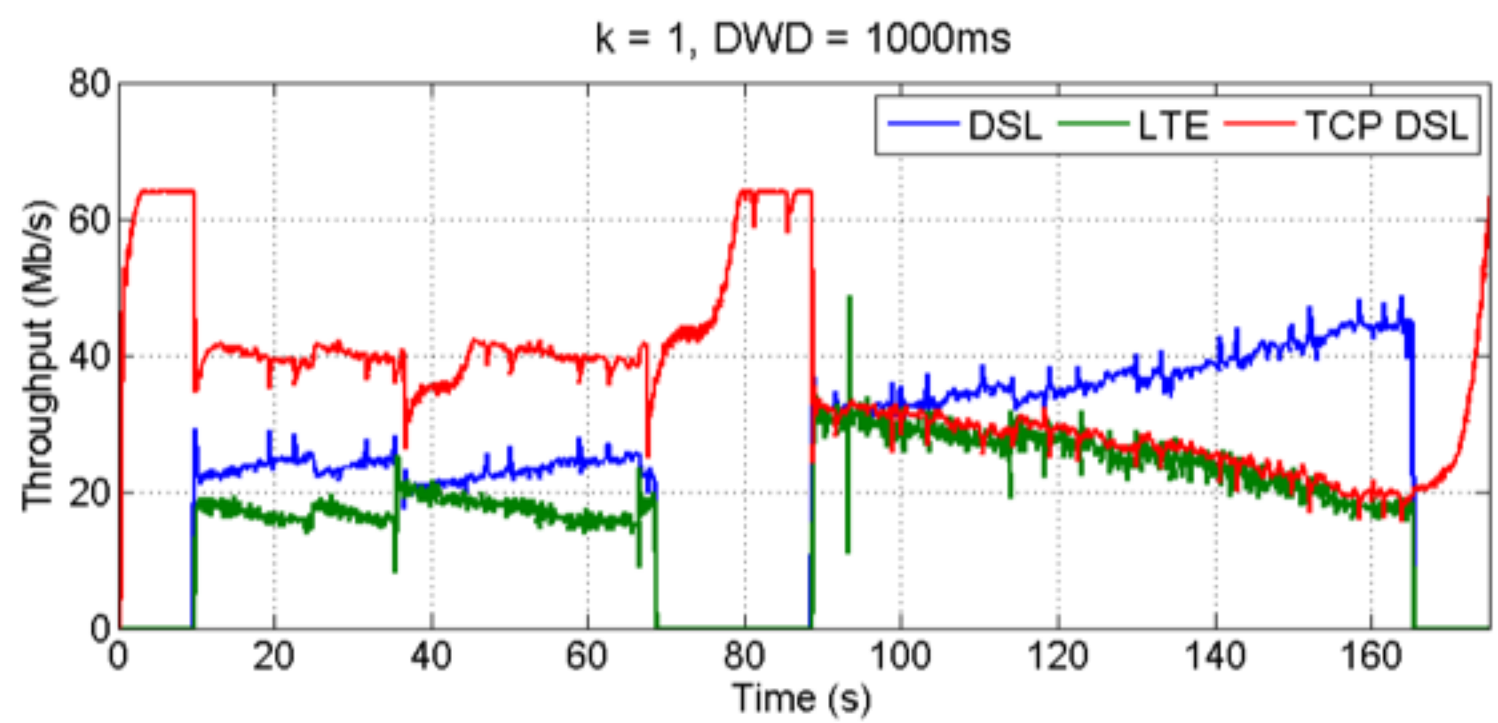
➡ k and T_{dwd} provide trade-off between aggressiveness and responsibility

Evaluation:
Results with TCP cross traffic

- $T_{dwd} = 50ms$: TCP flow only gets spare capacity
- $T_{dwd} = 1000ms$: UDP traffic permanently shifted to mobile link

➡ Operator can decide how TCP-friendly the algorithm should be





Conclusion

- **Goal:** Aggregation of DSL and mobile capacity for excess traffic
- Layer 3 bonding solution
  - Ingress: Packet mangling (SEQ#) and scheduling that adapts w_{mobile} dynamically
  - Egress: Re-ordering buffer
- Evaluation of parameters k and T_{dwd}
  - Trade-off between aggressiveness and responsibility
- **Future Work**
  - Interoperation with presently deployed MPTCP proxies
  - Middlebox cooperation to indicate if re-ordering sensitivity

Evaluation
Results for a multiple UDP flows