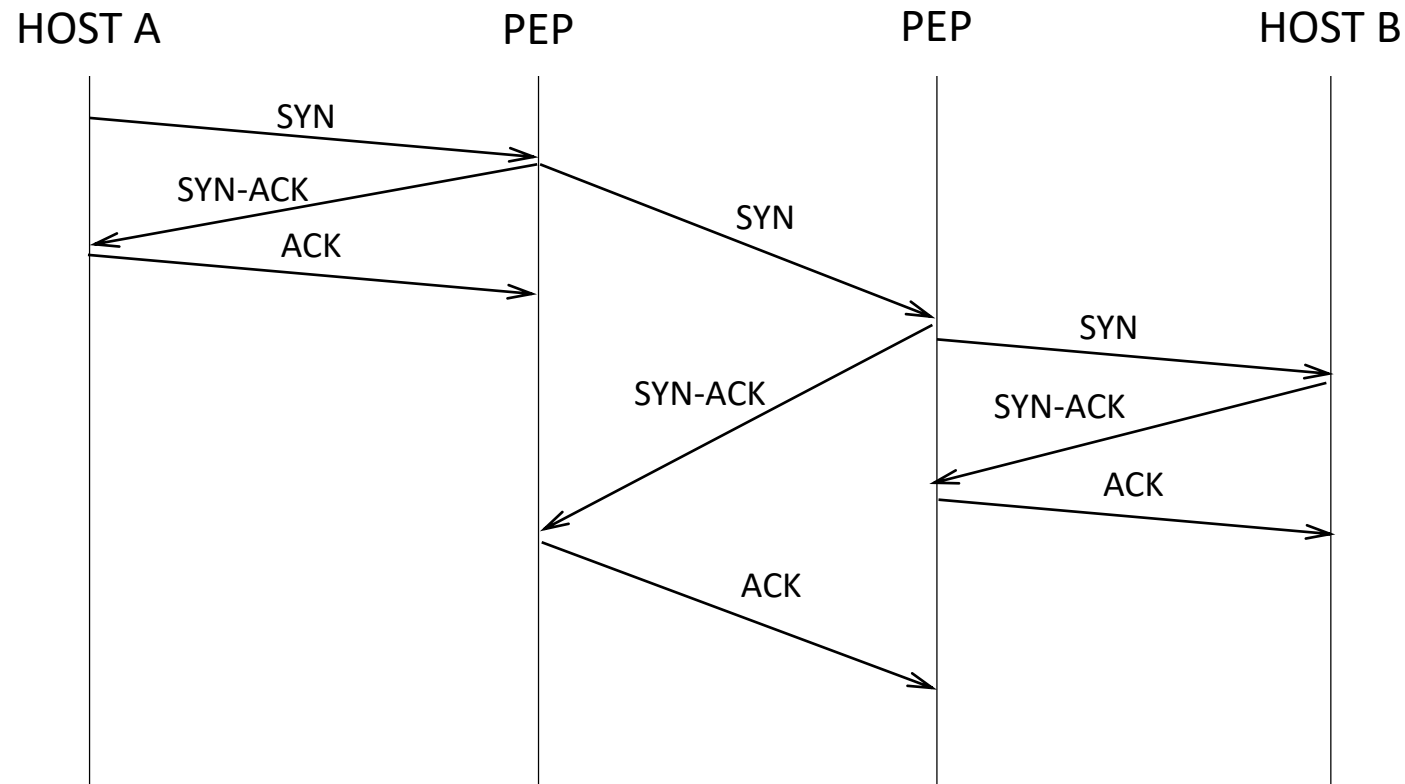


# Some experiments of MPTCP on satellite access



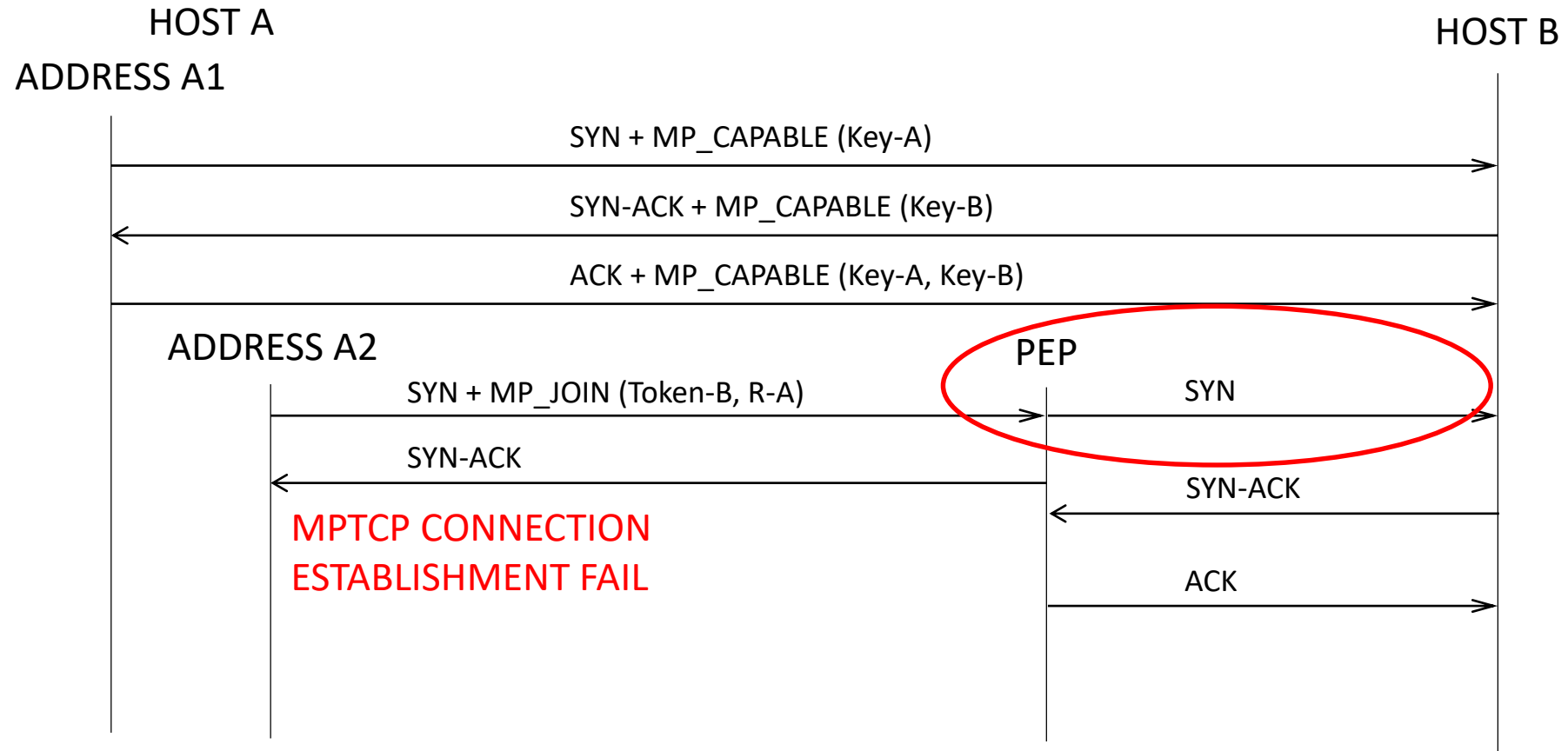
# Experiments of MPTCP on GEO satellite access

- SATCOM systems typically deploy TCP Proxy (PEP) [RFC3135]



# Experiments of MPTCP on GEO satellite access

- MPTCP connection establishment impacted by TCP Proxy

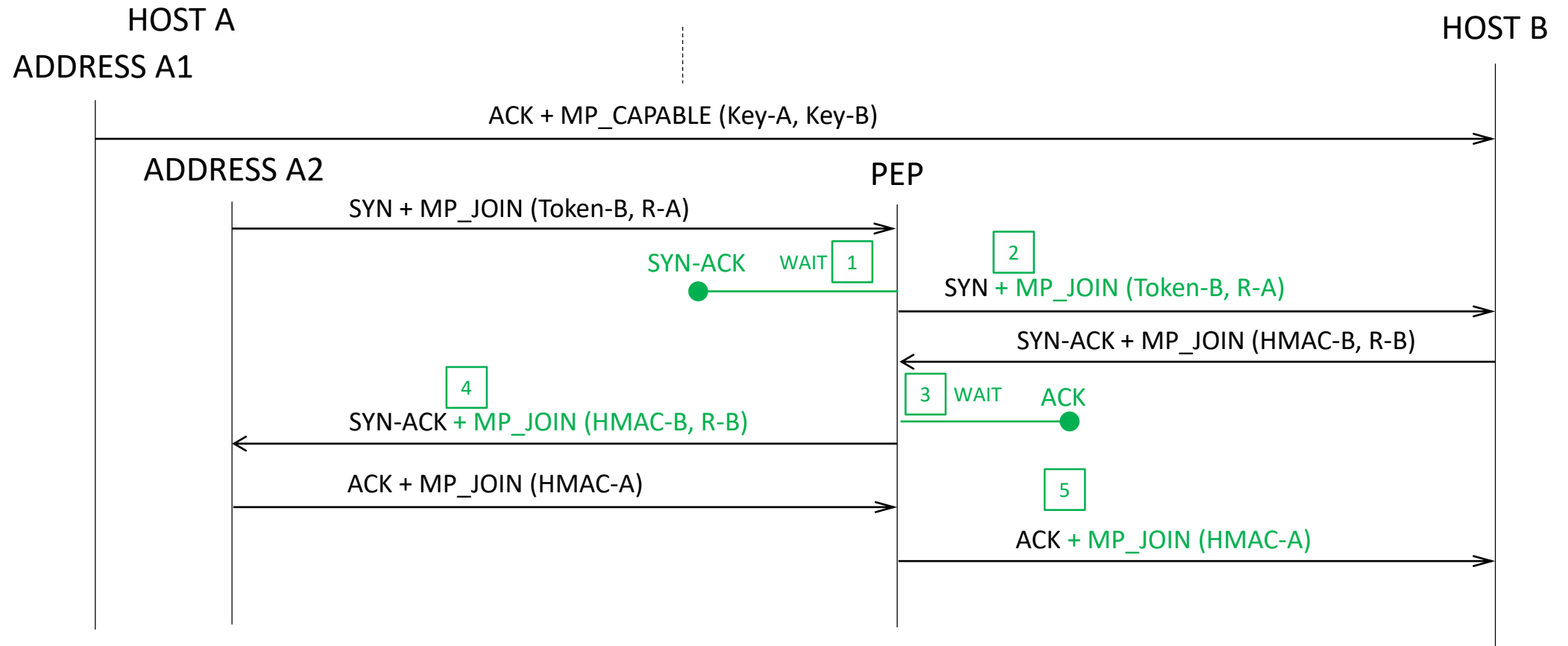


HMAC-A = HMAC(Key=(Key-A+Key-B), Msg=(R-A+R-B))

HMAC-B = HMAC(Key=(Key-B+Key-A), Msg=(R-B+R-A))

# Experiments of MPTCP on GEO satellite access

- Adaptation of the TCP Proxy (PEPSal) to enable MPTCP



HMAC-A = HMAC(Key=(Key-A+Key-B), Msg=(R-A+R-B))

HMAC-B = HMAC(Key=(Key-B+Key-A), Msg=(R-B+R-A))

# Experiments of MPTCP on GEO satellite access

- Issue #1: TCP Proxy client behaving as MPTCP client (without further modification to the TCP Proxy) and packet loss

|      |             |               |               |       |      |       |   |       |       |               |
|------|-------------|---------------|---------------|-------|------|-------|---|-------|-------|---------------|
| 1727 | 0.226913276 | 192.180.43.15 | 192.180.43.16 | MPTCP | 1514 | 44638 | → | 9999  | [ACK] | Seq=396693... |
| 1728 | 0.227331183 | 192.180.43.15 | 192.180.43.16 | MPTCP | 106  | 44638 | → | 9999  | [ACK] | Seq=396693... |
| 1729 | 0.227370835 | 192.180.43.16 | 192.180.43.15 | MPTCP | 74   | 9999  | → | 44638 | [ACK] | Seq=326349... |
| 1730 | 0.227376664 | 192.180.43.16 | 192.180.43.15 | MPTCP | 74   | 9999  | → | 44638 | [ACK] | Seq=326349... |
| 1731 | 0.227379806 | 192.180.43.15 | 192.180.43.16 | MPTCP | 1514 | 44638 | → | 9999  | [ACK] | Seq=396693... |
| 1732 | 0.230793803 | 192.180.43.15 | 192.180.43.16 | MPTCP | 106  | 44638 | → | 9999  | [ACK] | Seq=396693... |

Subflow A1 (without TCP Proxy)

Data Sequence Number: 1212051962 (32bits version)  
 Subflow Sequence Number: 1749829  
 Data-level Length: 1428

|      |             |               |               |       |      |                      |   |       |       |               |
|------|-------------|---------------|---------------|-------|------|----------------------|---|-------|-------|---------------|
| 1836 | 0.237624664 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1837 | 0.237785458 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1838 | 0.251695897 | 192.180.45.3  | 192.180.43.16 | MPTCP | 1494 | [TCP Retransmission] |   | 37157 | →     | ...           |
| 1839 | 0.258122775 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1840 | 0.258343652 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1841 | 0.258601289 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1842 | 0.260293705 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |

Subflow A2 (with TCP Proxy)

.... ..1 = Data ACK is present: 1  
 Original MPTCP Data ACK: 279130937  
 [Multipath TCP Data ACK: 1 (Relative)]  
 Data Sequence Number: 1212073382 (32bits version)

|      |             |               |               |       |      |                      |   |       |       |               |
|------|-------------|---------------|---------------|-------|------|----------------------|---|-------|-------|---------------|
| 1849 | 0.262002118 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1850 | 0.262115454 | 192.180.43.16 | 192.180.45.3  | MPTCP | 74   | 9999                 | → | 37157 | [ACK] | Seq=181369... |
| 1851 | 0.262230069 | 192.180.43.16 | 192.180.45.3  | MPTCP | 86   | [TCP Dup ACK 1850#1] |   | 9999  | →     | 3...          |
| 1852 | 0.236956716 | 192.180.43.15 | 192.180.43.16 | MPTCP | 1514 | 44638                | → | 9999  | [ACK] | Seq=396697... |
| 1853 | 0.237000593 | 192.180.43.15 | 192.180.43.16 | MPTCP | 106  | 44638                | → | 9999  | [ACK] | Seq=396697... |
| 1854 | 0.237042365 | 192.180.43.15 | 192.180.43.16 | MPTCP | 1494 | 44638                | → | 9999  | [ACK] | Seq=396697... |

Subflow A2 (with TCP Proxy)  
 acknowledge at MPTCP level

.... .0.. = Data Sequence Number, Subflow Sequence Number, Data-level Length, Checksum pres  
 .... ..0. = Data ACK is 8 octets: 0  
 .... ..1 = Data ACK is present: 1  
 Original MPTCP Data ACK: 1212074790

$$1212074790 = 1212073382 + 1408$$

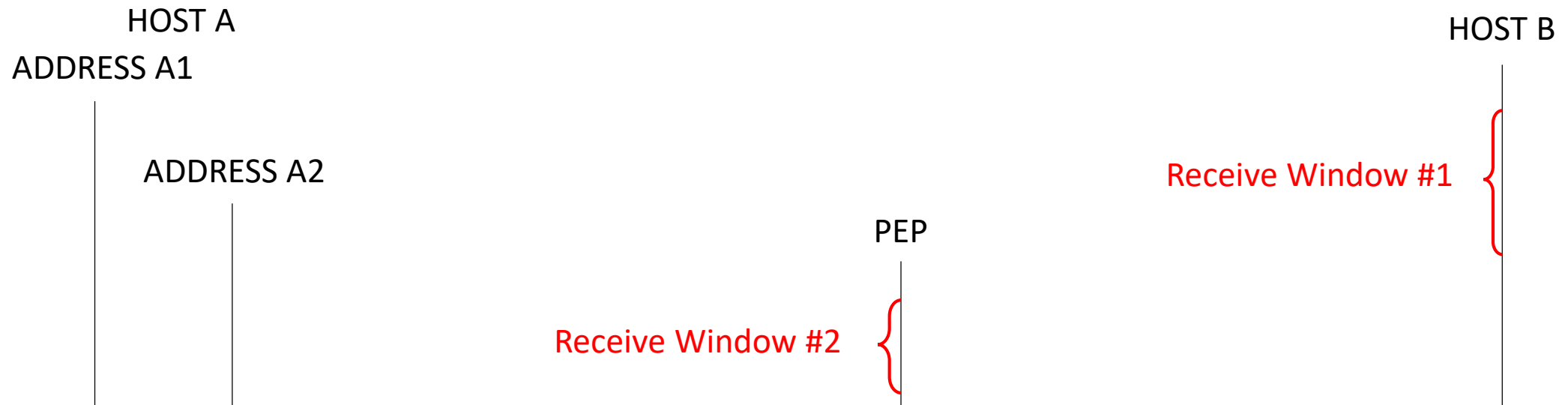
=> Issue if packet lost on subflow A1

# Experiments of MPTCP on GEO satellite access

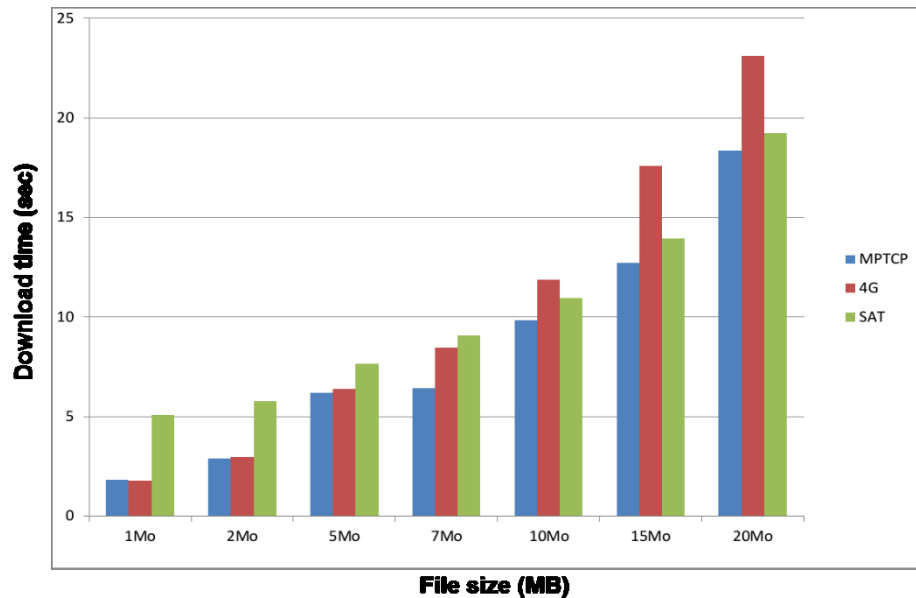
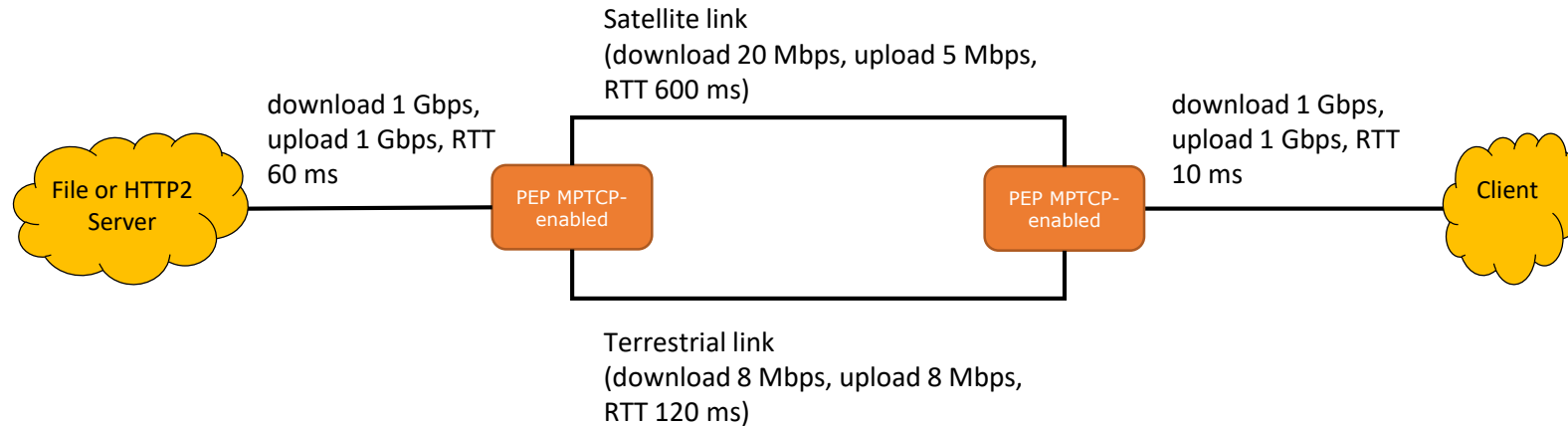
- Issue #2: TCP Proxy client behaving as MPTCP client (without further modification to the TCP Proxy) and flow control

Regular TCP advertises a receive window in each packet, telling the sender how much data the receiver is willing to accept past the cumulative ack. The receive window is used to implement flow control, throttling down fast senders when receivers cannot keep up.

MPTCP also uses a **unique receive window**, shared between the subflows.

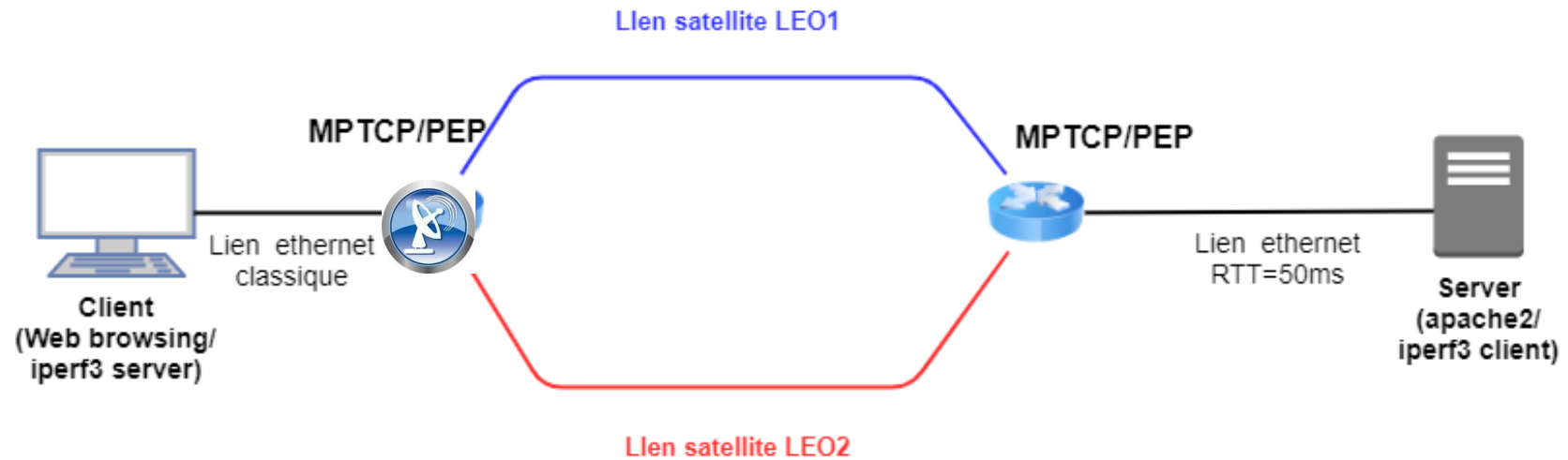


# Experiments of MPTCP on GEO satellite access

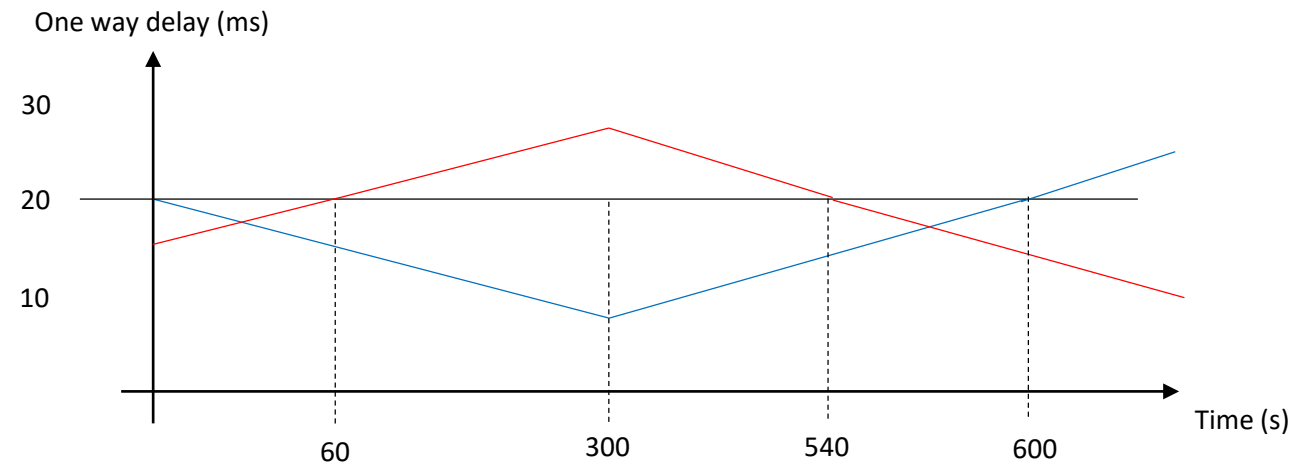


- Tests with a PEP MPTCP-enabled
- Despite the large asymmetry, MPTCP takes the best out of the cellular and SATCOM accesses (except for small files)

# Experiments of MPTCP on LEO satellite access

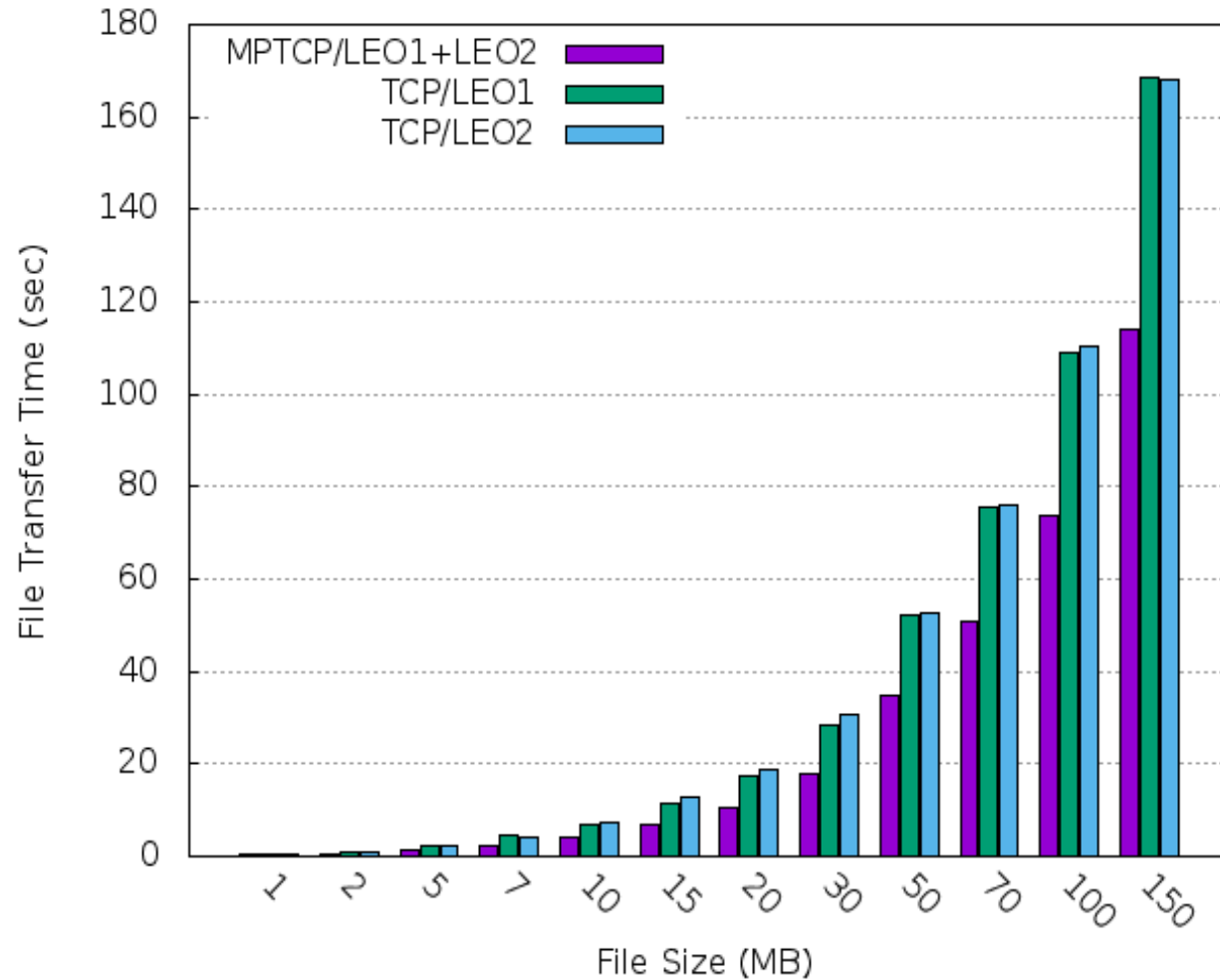


- Variable delay on the low-earth orbit satellites
- 8 Mbps on each satellite link
- Single vs multiple path

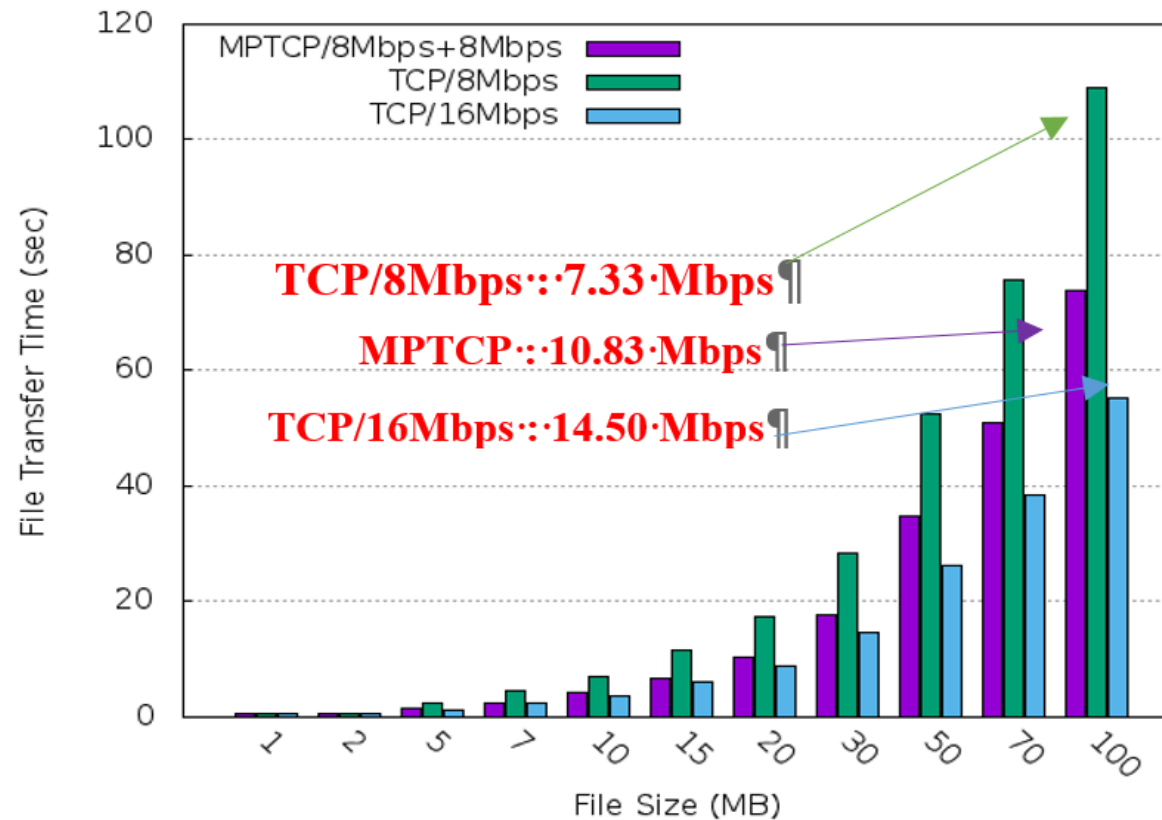




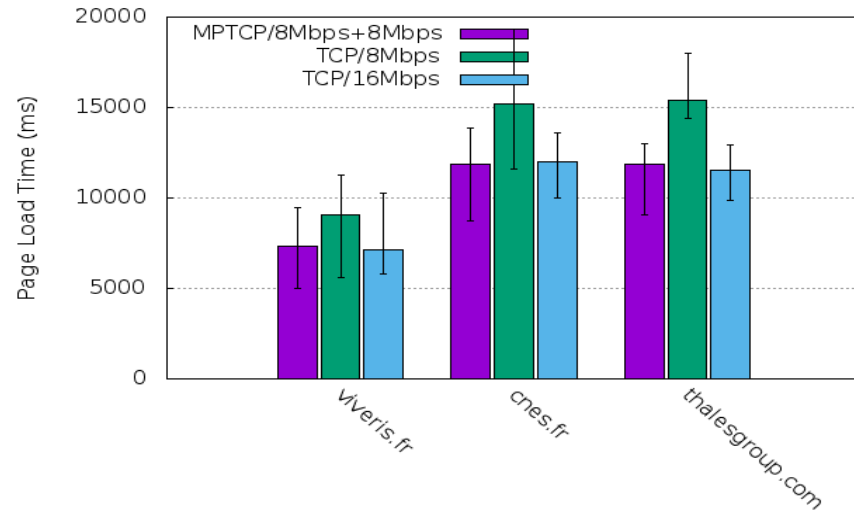
# Experiments of MPTCP on LEO satellite access



# Experiments of MPTCP on LEO satellite access



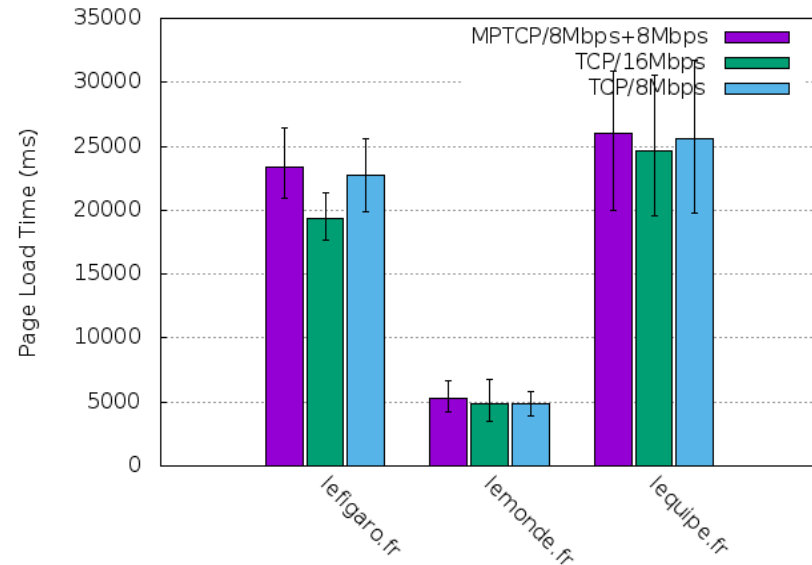
# Experiments of MPTCP on LEO satellite access



| SITE            | Size in MB | PROTO    | Other domains |
|-----------------|------------|----------|---------------|
| Viveris.fr      | 1.12       | HTTP/2.0 | 3 en HTTP/2.0 |
| Cnes.fr         | 8.42       | HTTP/1.1 | 4 en HTTP/2.0 |
| Thalesgroup.com | 12.38      | HTTP/1.1 | 8 en HTTP/2.0 |

- For pages with a low amount of redirections to other domains or in HTTP1.1
  - MPTCP (8 Mbps + 8 Mbps) performs as good as TCP (16 Mbps)

# Experiments of MPTCP on LEO satellite access



| SITE        | Size in MB | PROTO    | Other domains         |
|-------------|------------|----------|-----------------------|
| Lefigaro.fr | 21.25      | HTTP/2.0 | 32 en HTTP/2.0 et 1.1 |
| Lemonde.fr  | 1.51       | HTTP/2.0 | 5 en HTTP/2.0         |
| Lequipe.fr  | 3.48       | HTTP/2.0 | 36 en HTTP/2.0 et 1.1 |

- For pages with lots of redirections or in HTTP2.0
  - MPTCP (8 Mbps +8 Mbps) performs as TCP (8 Mbps)
  - TCP (16 Mbps) shows a lower PLT

# Conclusion of the experiments

- TCP Proxys block MPTCP traffic
- Adaptation of TCP Proxy is not simple
- Important web pages diversity makes it hard to compare MPTCP with TCP
  
- For those interested in SATCOM
  - Workshop on QUIC for high BDP network
  - Details : <https://trac.ietf.org/trac/ietf/meeting/wiki/106sidemeetings>
  - Time : 3pm30 – 4pm30 on Wednesday
  - Where : Bras Basah

# Open Source tools

- OpenBACH : open-source test orchestrator

<http://www.openbach.org/content/home.php>



- OpenSAND : open-source SATCOM emulator

<http://opensand.org/content/home.php>



- PEPSal : open-source PEP

- CESARS : CNES open plateforme for real satellite experiments

<https://entreprises.cnes.fr/fr/accueil-cesars>